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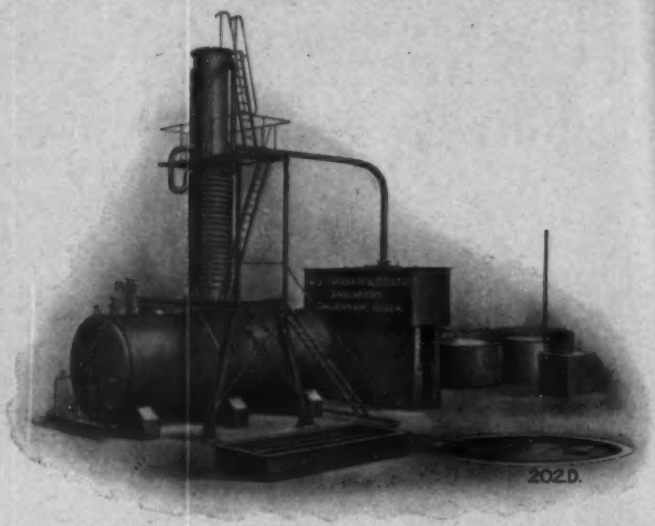

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CONTENTS.

	PAGE
Council and Officers	i–ii
Committees	ii–iv
General Notices :—	
Copyright	v
Issue of Journal	vi
Changes of Address	vi
Papers and Articles	vi–vii
Binding of Journals	vii
Reprints of Papers	vii
Bibliography and Abstracts	vii
Medal for Student Members	vii
Advertisements	vii–viii
Appointments Register	viii
Library	viii–x
Personal Notes of Members and Special Notices	x
Annual Report on the Progress of Naphthology ..	xi
Sixth Annual Dinner	xi
Empire Mining and Metallurgical Congress	xi

PAGE

Department of Scientific and Industrial Research .. xii

Current Petroleum Notes xii

Electricity Applied to the Winning of Crude Petroleum, with Special Reference to the Yenangyoung Field, Burma, by C. H. McCarthy-Jones, M.I.Mech.E., M.I.E.E. 115

Annual Report of the Council, 1923 156

Eleventh Annual General Meeting 163

The Engineer in Relation to the Petroleum Industry, by H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng. (Presidential Address) 168

Sixth Annual Dinner 183

The Hypochlorite Process, by A. E. Dunstan, D.Sc., F.I.C., F.C.S. 201

Petroleum Ash, by W. H. Thomas, A.R.S.M. 216

Some Characteristics of the Hydrocarbons in Mid-Continent Kerosene, by C. R. Wagner 220

Reviews 225

Current Bibliography, compiled by W. J. Wilson, F.I.C., A.C.G.I. .. .. 51 A

Abstracts, compiled by S. Bowman, F.I.C., P. Dvorkowitz, Ph.D., H. Moore, A.I.C., F.C.S., F. G. P. Remfry, B.A., D.Sc., A.I.C., T. A. Smith, B.Sc., F.I.C., and W. G. Weeks, A.R.S.M., A.R.C.S., F.G.S. .. .. 93 A

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Issue of Journal. The Journal is published in six bi-monthly parts per volume, viz., February, April, June, August, October and December. A brochure giving the History, Regulations and List of Members of the Institution was published in January, 1923, and the revised List of Members will be published periodically.

All members receive these publications free of cost. Additional copies of the Journal are charged at the rate of 7s. 6d. per part, unless otherwise stated, and of any other publication at the price stated on the wrapper.

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English equivalents of foreign weights and measures should be given, and it is suggested that a bibliography of the subject dealt with be appended.

All papers and articles submitted are assumed to be original communications unless otherwise stated, in which case reference to the previous publication should be given.

Members are invited to submit papers to be read at the General Meetings of the Institution, and are specially asked to forward articles for publication in the Journal.

Members desiring to receive advance galley proofs of papers to be read before the Institution should apply to the Secretary, informing him of the address to which the proof is to be sent.

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This notice applies to all previous volumes.

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Orders for extra reprints should be sent to the printers when the manuscript is forwarded to the editor.

Bibliography and Abstracts. A bibliography of current literature is published with each issue of the Journal, together with abstracts of the more important articles and patent specifications, this supplement being paged separately to the Transactions. In order to make this section of the maximum value, members are requested to send any matter which may have been inadvertently overlooked to the editor.

Medal for Student Members. A medal and a prize of five guineas will be awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented a paper of outstanding merit during the session.

Advertisements. A number of Advertisements are inserted in the Journal, and information as to terms, etc., can be obtained from Mr. H. J. Humm, 93 and 94, Chancery Lane, London, W.C. 2. (Telephone No.: Central 8106).

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Appointments Register. A register of members requiring appointments is kept at the office of the Institution for the convenience of firms requiring the services of petroleum technologists, etc., it being understood that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library may be consulted between the hours of 11 a.m. and 4 p.m. daily. The additions made to the current and standard literature on petroleum and allied substances, since the publication of the last Journal, are :—

From the Iron and Steel Institute :—

Proceedings, Vol. CVIII., No. II., 1923, and By-Laws and List of Members.

From the Institution of Mechanical Engineers :—

Proceedings, Vol. II., 1923.

Handbook of Natural Gas. By Henry P. Westcott. 3rd Edition. 1920.

For Review :—

From the Business Code Co., U.S.A., "Oil and Gas Code, 1923."

Fuel Oils and their Applications. By H. V. Mitchell, F.C.S.

Emergency Water Supplies. By A. Beeby Thompson. 1924.

From Chapman & Hall, Ltd., "Measurement, Compression and Transmission of Natural Gas." By Lester Clyde Lichty. 1924.

From the Imperial Mineral Resources Bureau :—

The Mineral Industry of the British Empire and Foreign Countries.

Coal-Mining Accident *Statistics*, 1912-22.

Statistics, 1919-21. Borates, Felspar, Manganese, Nitrates, Pyrites, Platinum and Allied Metals, and Sulphur.

Statistics, 1913-1919. Petroleum and Allied Products.

Fifth Annual Report of the Governors of the Imperial Mineral Resources Bureau. Report on a proposed uniform method of recording Mining and Metallurgical Statistics.

CANADA.

Report of the Dept. of Mines, for the Fiscal Year ending March 31st, 1923, Ottawa.

Department of Mines, Geological Survey, Memoir 135. Geology of Fraser River Delta Map-area. By W. A. Johnston.

Summary Report on Mines Branch Investigations, 1922.

Facts about Peat. By B. F. Haanel. No. 614, 1924.

From the Canadian Government Trade Commission :—

Petroleum Western Canada.

From the High Commissioner for Canada :—

North-West Territories and Yukon Branch, Mining Development in the Mackenzie District, 1922 ; and Mineral Possibilities in the Port Arthur District, Ontario.

AMERICA.

From the U.S. Bureau of Mines Dept. of the Interior :—

Technical Paper 324. "Uses of Water in the Oil-Shale Industry," with particular reference to engineering requirements. By J. J. Jakosky. With a chapter on "The Sanitation of Oil-Shale Camps." by A. L. Murray.

Serial No. 2588. Report of Investigations. "Fractional Eduction of Oil from Oil Shale." By Martin J. Gavin and Lewis C. Karrick.

U.S. Geological Survey :—

Forty-fourth Annual Report of the Director of the U.S. Geological Survey to the Secretary of the Interior, 1923.

Bulletin 749. Geology of the Tullock Creek Coal Field, Rosebud and Big Horn Counties, Montana. By G. Sherburne Rogers and Wallace Lee.

Bulletin 760-*A*. Pedestal Rocks in the Arid South-West. By Kirk Bryan.

Water-Supply Papers :—

No. 502. Surface Water Supply of the U.S. 1919-1920. Part II. South Atlantic Slope and Eastern Gulf of Mexico Basins.

No. 505. Part V. Hudson Bay and Upper Mississippi River Basins.

No. 520-*A*. Variation in Annual Run-off in the Rocky Mountain Region.

No. 524. Part IV. St. Lawrence River Basin.

No. 528. Part VIII. Western Gulf of Mexico Basins.

The Council would be grateful to members who are authors of books on petroleum or on allied substances if they would kindly present a copy of their works to the Library of the Institution, and for review in the Journal.

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Dr. J. A. L. Henderson sailed for Trinidad, on February 16th, last, and expects to be absent from England until about the middle of April.

Mr. T. D. Haslett is now in India.

Mr. J. A. Kind has returned from Algeria.

Mr. J. M. Muir is on his way back to England.

Mr. N. Sutherland is returning to England.

Lieut.-Colonel. Sir A. T. Wilson is on his way to England.

Mr. C. W. Wood is now in England.

Mr. F. E. Keep is now in England.

Mr. C. H. Perkins has returned to Rumania.

Mr. S. Raymond Prisk is now in England.

Mr. James Kewley has gone abroad.

Mr. H. F. Warrington Morris has returned from Burma.

Dr. A. E. Dunstan, the Honorary Editor, has been elected to the Council of the Chemical Society.

Dr. J. A. L. Henderson is returning from Trinidad, *via* Canada, and is expected to arrive early in May.

Mr. A. P. Faickney has been appointed Works Manager to the British Burmah Petroleum Co., Rangoon, after having officiated in that position for nearly a year.

STANDARDIZATION COMMITTEE.

Mr. C. V. Hill has very kindly consented to act as Honorary Secretary to the Standardization Committee.

ANNUAL REPORT ON THE PROGRESS OF NAPHTHOLOGY.

It is proposed to devote annually one issue of the Journal to a Report on the Progress of Naphthology during the preceding year. As far as possible it is intended that this Report shall cover the industry in all its aspects, and members having special knowledge of progress in any particular branch are requested to forward such information to the Honorary Editor by the end of March if possible. The Report for 1923 will appear in the June number of the Journal.

SIXTH ANNUAL DINNER.

The Sixth Annual Dinner of the Institution took place at the Connaught Rooms, Kingsway, London, W.C. 2, on March 18th, 1924, and a full report of the speeches will be found in this Journal. The total number of members and guests seated was 215, and an excellent menu was served. The Rt. Hon. the Viscount Chelmsford, P.C., G.C.S.I., G.C.M.G., G.C.I.E., G.B.E., had arranged to be present, but was, unfortunately, detained by his duties in the House of Lords, and he subsequently wrote expressing his regret at being unable to attend.

On arrival, the members and guests were received by the President (Mr. H. Barringer). The thanks of the Institution are due to Mr. Ashley Carter and Mr. William Sutton, for arranging the Dinner, and to Mr. George Sell for carrying out the seating arrangements and preparing two table plans illustrated with drawings representative of the various phases of the Petroleum Industry.

EMPIRE MINING AND METALLURGICAL CONGRESS.

His Royal Highness Prince Arthur of Connaught will be the principal guest at the Official Banquet of the Empire Mining and Metallurgical Congress. The Banquet will be held at Guildhall by the courtesy of the City Corporation, on Thursday, June 5th. The Lord Mayor and other distinguished guests will also be present, including official delegates from all parts of the Empire. The Sessions of the Congress will be held at the British Empire Exhibition from June 3rd to 6th inclusive, for which the various conference halls have been placed at the disposal of the convening bodies by the exhibition authorities.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

The Lord President of the Council has appointed Mr. F. S. Sinnatt, M.B.E.(Mil.), M.Sc.(Tech.), F.I.C., M.I.Min.E., to be Assistant Director of Fuel Research, as from April 1st.

Mr. Sinnatt is lecturer in fuels in the University of Manchester, Faculty of Technology. He is also Director of Research to the Lancashire and Cheshire Coal Research Association, and has been in charge of the physical and chemical survey of coal seams which the Association is carrying out for the Fuel Research Board in the Lancashire and Cheshire coalfields.

CURRENT PETROLEUM NOTES.

The receipt of notes of interest for insertion under this heading will be welcomed by the Editor.

CANADA.—The Dominion Bureau of Statistics, Ottawa, estimates the production of petroleum in Canada during 1923 as 176,000 barrels, as against 179,068 barrels in 1922. The value of the 1923 production is estimated at $583,000, the value for 1922 being $611,176.

OIL POSSIBILITIES OF THE LOWER FRASER VALLEY, BRITISH COLUMBIA.

The Geological Survey Branch of the Canadian Department of Mines has just published a report by Mr. W. A. Johnston on the geology of Vancouver and its vicinity. It is accompanied by a geological map of the area lying between Burrard inlet and the International Boundary, and extending from Port Haney west to the Straits of Georgia. A detailed description is given of the geological formations underlying the area. Of special interest is the chapter on economic geology in which there is a careful and unbiased consideration of the question of the oil and gas possibilities. A copy of the report can be had by applying to the Director of the Geological Survey, Ottawa, or 510, Pacific Building, Vancouver.

No. 42. Vol. 10.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The Seventy-sixth General Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, London, W.C. 2, on Tuesday evening, February 12th, 1924, the Chair being taken by the President, Mr. H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A.

The Secretary first read the names of newly elected members, as follows :—

Members.—Stanley Bowman, Simon Papp, Geoffrey Lawrence Parsons.

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Associate Members.—James Cuthill, Cecil William Dannatt, Arthur L. Davis, John Raymond Stuart Hawker, Graeme Campbell Orr, Horace Arthur Richards.

Transference from Student.—Cecil Evelyn Keep.

Students.—Maung Ba-Yan, George Anderson Galbraith, Constantin George Iovitzoin, Herbert Montagu Dawson Lowry, Dundas Maxwell Gobell Sneddon, David James Alexander Stewart.

Associates.—William James Caldwell, Stuart Harold Howard.

And the following paper was then read :—

Electricity Applied to the Winning of Crude Petroleum, with Special Reference to the Yenangyoung Field, Burma.

By C. H. McCarthy-Jones, M.I.Mech.E., M.I.E.E. (Member).

The economical production of crude oil is a problem of peculiar interest to the members of this Institution; in fact, it may be claimed in a wider sense of vital importance to the civilised world in general. If the supplies of oil are in excess of the requirements at the moment, it is a temporary situation, and the outlook for the future, with the practical certainty of increasing demand and diminishing resources, is not reassuring. Any system of winning oil which offers opportunity of better efficiency and conservation of oil supplies therefore calls for careful and sympathetic examination.

Five years ago the author had the privilege of listening to a paper read before this Institution on "The Application of Electrical Power to Oil Field Requirements,"* but in view of the importance of the subject, the developments which have taken place since that date, and the marked economies which this method of working effects, it needs no apology for introducing the matter to your attention again. Indeed, it is a little surprising that, with certain notable exceptions, more advantage has not been taken of the facilities and indisputable benefits which the application of electrical energy affords.

It is the purpose of this paper more particularly to describe the steps which have been taken by the Burmah Oil Co., Ltd., and certain Oil Companies operating in the same territory, to conserve their oil supplies by means of this application. This scheme forms the largest and boldest attempt which has yet been initiated by any single company to reduce the cost of operating an oil field to the lowest possible limit, and thereby extend, not only the life of the field, but the degree of exhaustion which can be economically attained.

Before dwelling on this scheme, however, it may be well to recapitulate briefly the engineering problems involved, and to refer to certain specific results which have been secured by applying this form of power to the winning of crude oil.

Fundamental Considerations.

The process of recovering crude oil involves three fundamental engineering considerations :—

1. Drilling the well.
2. Recovering the oil from the well when it is drilled, and
3. The transport of the oil when it has been recovered.

The second consideration does not arise when the natural gas pressure in the oil-sand is sufficient to expel the oil without the application of any extraneous power. If gas pressure were constant and sufficient the problem of lifting the oil would not arise, but, with certain exceptions, and particularly when faced with fields of diminishing output, the bulk of the oil must be lifted mechanically from its reservoir in the earth before we can make effective use of it.

It will not be disputed that in the past, and even to-day, the operations indicated above have only been accomplished at the cost of a prodigal expenditure of crude oil, or equivalent fuel. Waste and extravagance are inherent, in one form or another, to any system which employs a separate prime mover for the operations of each individual oil well. This is equally true, whether the

* J. W. Burford, *Journ. Inst. Petr. Techn.*, 4, 16, p. 229. 1918.

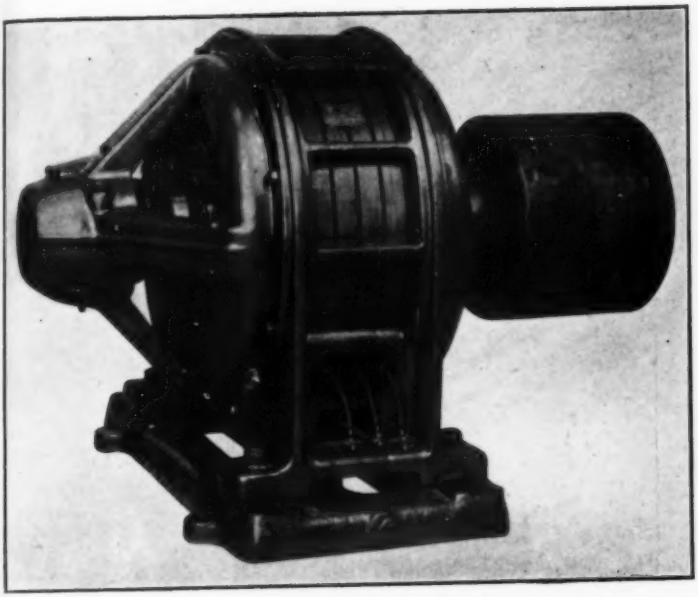

FIG. 1.

75-H.P. DRILLING MOTOR.

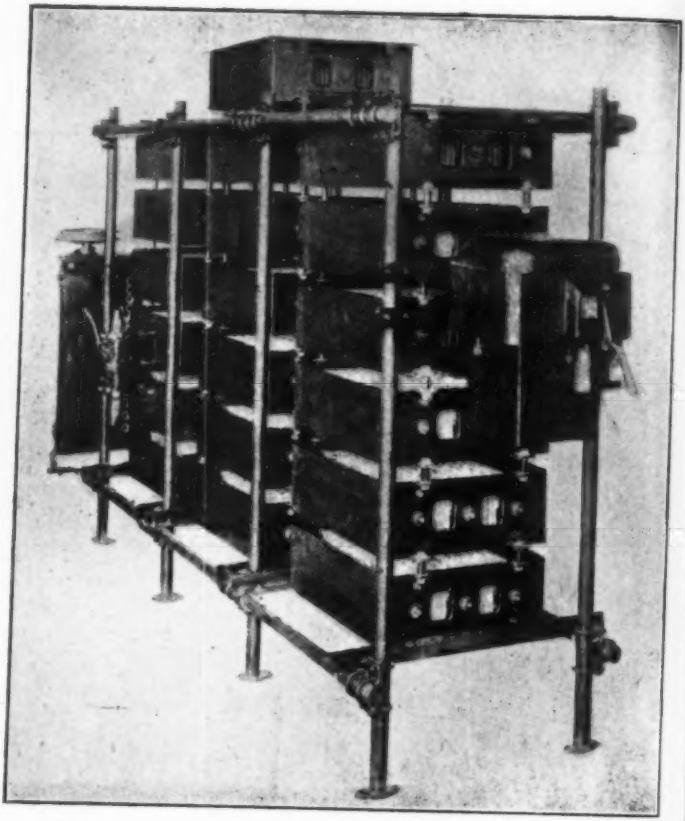

FIG. 2.

CR-9141 OIL-WELL-DRILLING MAIN AND AUXILIARY RESISTORS WITH CR-3202 DRUM CONTROLLERS AND K-20 OIL-CIRCUIT BREAKER.

prime mover is actuated by steam, gas or oil, so that although the economy of production may vary according to the particular type of engine employed, one cannot evade the ultimate issue, namely, that for the most economical operation of a field, the prime movers must be concentrated in as few and as large units as possible. There is only one method by which this can be satisfactorily effected to-day, and that is by means of electrical generation and distribution. The application of this power to the three fundamental processes mentioned will be considered briefly in more detail.

Drilling.

The different methods of drilling a well may be divided broadly into either the percussive or rotary system. The various ways of applying these two systems on different fields is not a matter which calls for detailed description in this paper.

Until the advent of the electrical motor, the steam engine was employed almost universally for drilling work. In some respects it is admirable for the purpose, robust, simple in design, very sensitive to speed control, and with heavy overload capacity; but it suffers from the drawback that it is extremely inefficient in itself, and leads to further inefficiency in the system of steam generation which it involves. It remains to-day, however, the chief medium for drilling work, and for isolated or "wild cat" wells, remote from the area of any existing electrical supply, is likely to hold this position for some time to come.

The horse-power required for drilling purposes varies with the system used, and the depth and size of hole proposed. The figures which are sometimes quoted are apt to be misleading, unless precise conditions are stated at the same time; thus, with the cable tool system it has been stated that the power in actual drilling operation varies from 15 to 25 h.-p., but the investigation which the author has made, and the records which he has secured, show that considerably heavier loads than this are encountered, depending on the formation drilled through, the depth of the well and the size of the tool employed. However, the actual power taken during drilling operation does not usually determine the capacity of the motor, because heavier loads are experienced when bailing the detritus, and the heaviest usually when handling casing.

The development of motor plant suitable for drilling purposes has been gradual, and a variety of different designs has been introduced from time to time. When the author first studied this application, about twelve years ago, it was frequently prophesied that no motor could provide the degree of flexibility required for the cable tool system of drilling, but the plant which is available to-day

reproduces all the essential characteristics of the steam engine, and apart from the economy effected, is in many respects superior.

The main requirements of a motor for operating the percussion system of drilling are as follows :—

1. The motor must be extraordinarily robust in design and capable of withstanding the rough usage and the racking strains which drilling entails.
2. It must have a free-fall characteristic on the downward stroke, so as to utilise the stretch of the cable in the manner distinctive of an effective percussive blow.
3. It must be capable of very wide and close speed control, so as to provide the best motion of the tools under the varying conditions of depth and weight which obtain.
4. It must have exceptional overload torque capacity to deal with the high value of the temporary loads which bailing and handling long lengths of casing entail.
5. The inertia of the moving parts must be kept as low as possible.

These features have all been satisfactorily developed in modern motor plant, designed for oil-well work.

Owing to their robust character and low maintenance costs alternating current motors have proved more satisfactory than continuous current machines, and in actual practice are now almost invariably employed. Apart from their inherent advantages as machines for oil field conditions, they lend themselves more readily to the distribution problems which are encountered in work of this nature. The free-fall characteristic required for drilling is obtained by loading the rotor circuit with sufficient resistance to ensure the proper motion of the tools. The very fine speed graduations are secured by means of two controllers, one of which supplies the coarse regulation, and the second the fine regulation ; thus every step which the main controller makes can be varied by the secondary or auxiliary controller, and in this manner about 80 different running points obtained. Both controllers are operated by means of telegraph cord from rope-wheels mounted at the headache post, so that in this respect the driller occupies the same position as with the earlier steam engine drive.

Figs. 1 and 2 show a typical drilling motor and its control gear, and Fig. 3 the diagram of connections. The more usual arrangement of the plant is shown in Fig. 4. It will be observed that the belt drive on the bandwheel is adhered to, the countershaft taking the place of the steam engine, and the motor being belted to it. Hitherto attempts which have been made to eliminate the belt drive between the motor and countershaft

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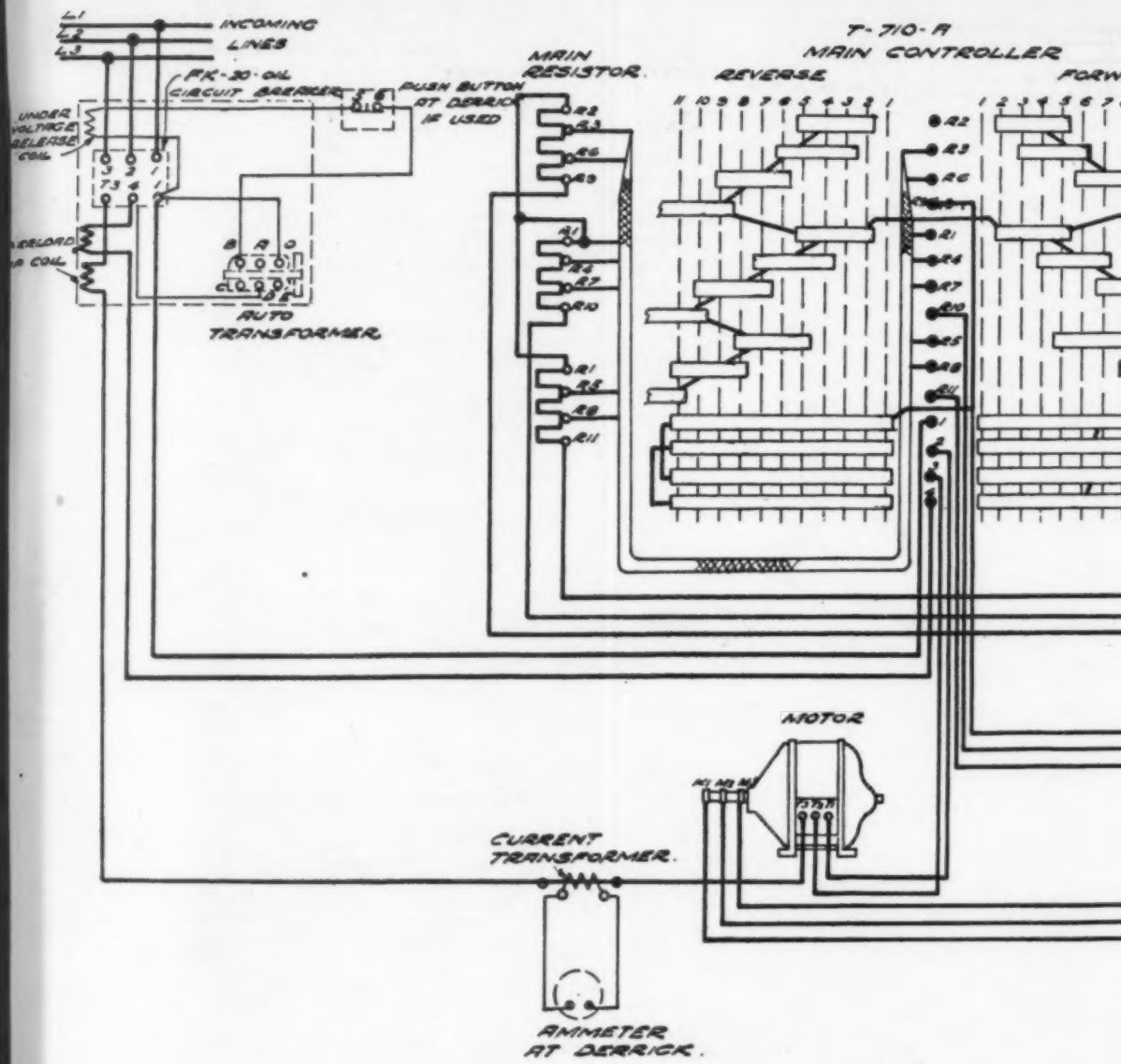
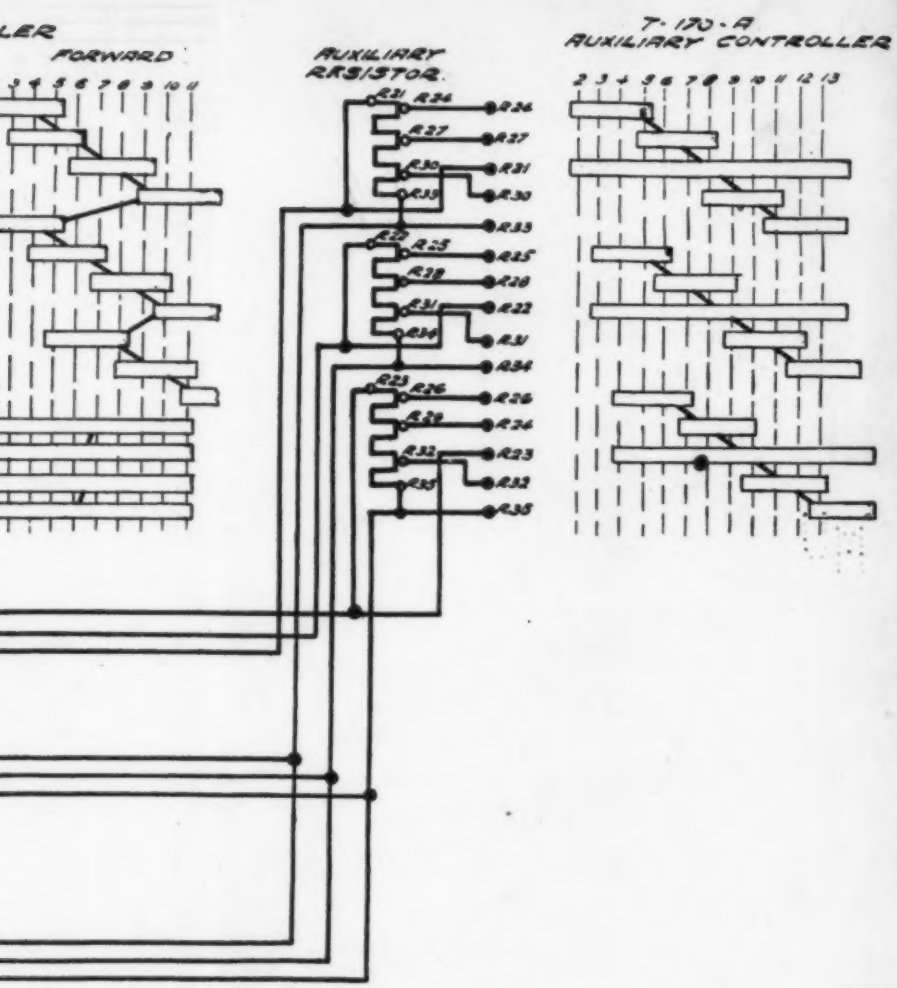


FIG. 3.

WIRING DIAGRAM OF 75-H.P. DRILLING MOTOR.


LER
FORWARD
AUXILIARY
RESISTOR.
T. 170. A
AUXILIARY CONTROLLER
2 3 4 5 6 7 8 9 10 11 12 13
R21 R24 R24
R27 R27
R30 R21
R33 R30
R33
R25 R25
R28 R28
R31 R22
R34 R31
R34
R23 R26 R26
R29 R24
R32 R23
R35 R33
R35

G MOTOR.

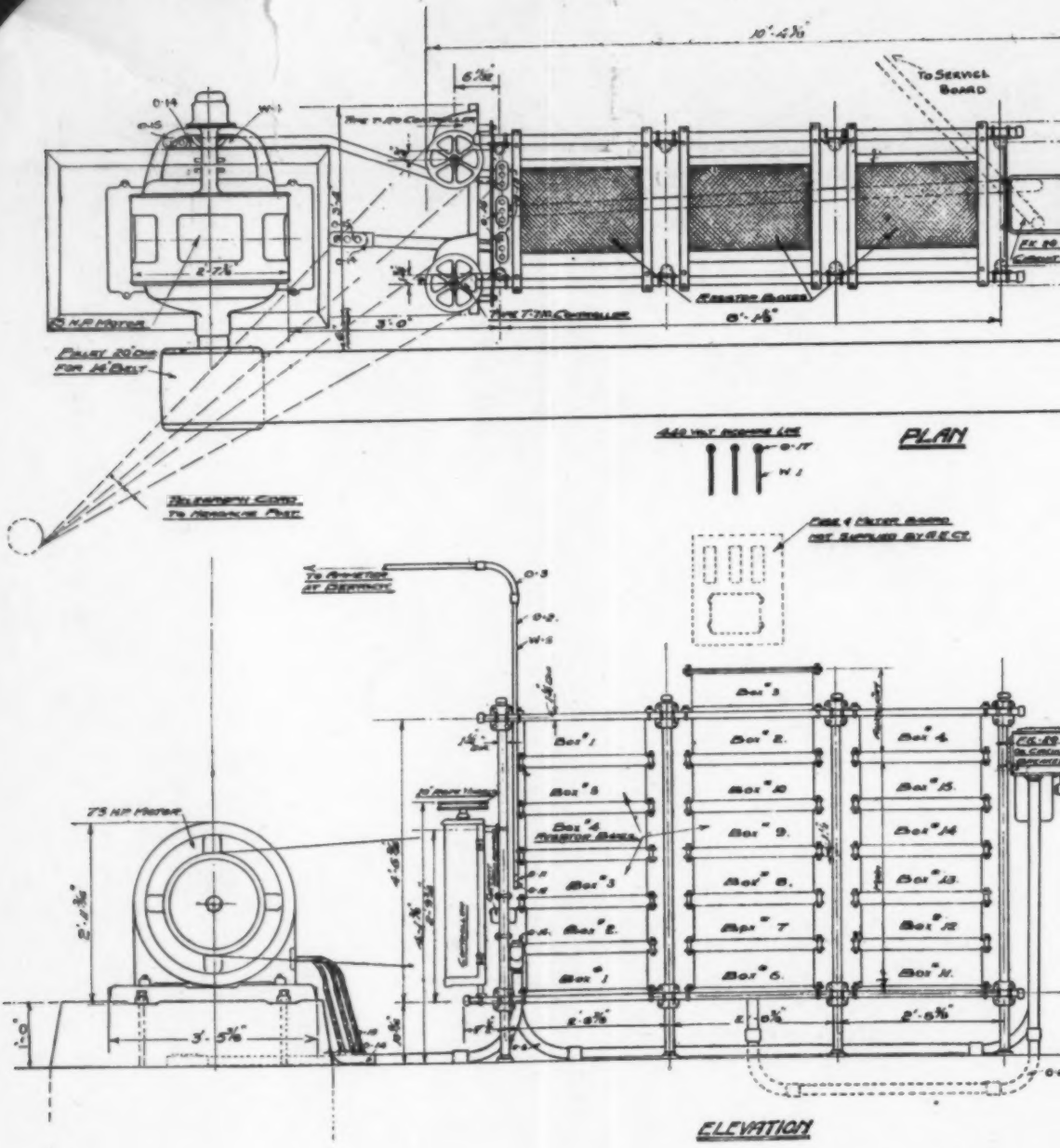
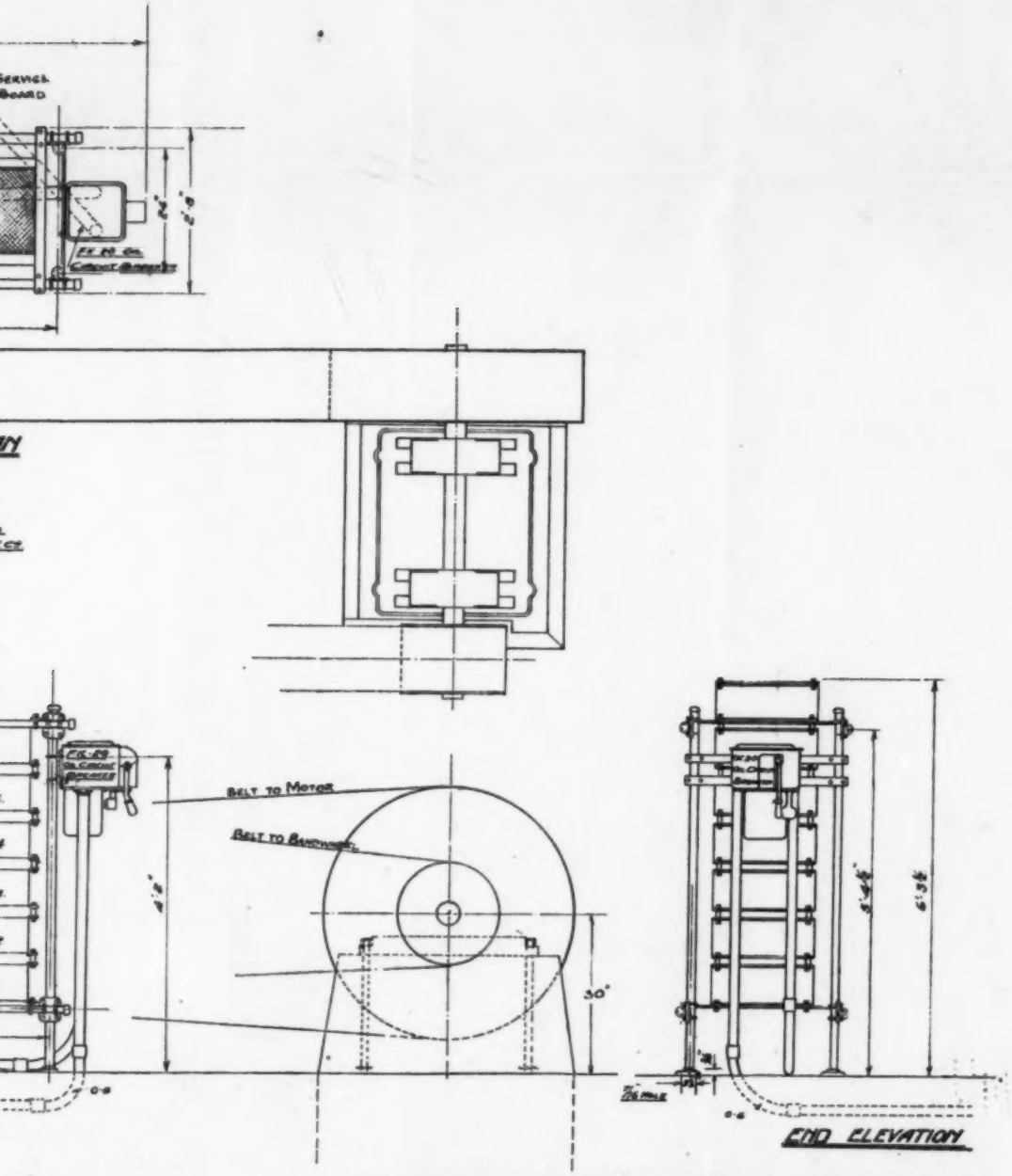


FIG. 4.

75 H.P. OIL WELL DRILLING EQ



G. 4.

DRILLING EQUIPMENT.

Note.—(1) Stack resistor boxes with terminals on side farthest from belt and with terminals on same end of each box.

(2) Open resistor wiring W.3. Non-ignitable cable.

Note.—See Dr.L.1924290 for wiring diagram. Dr.P.2026217 for clamped pipe assembly.

Notice to Purchaser.—Refer to contract for material to be supplied by the General Electric Co. The amount of such material is not increased by anything shown upon this drawing.

Note.—Numbers with prefix refer to schedule of material K.1940596.

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by introducing reduction gears, have not been entirely successful. The duty on the gears is so severe that in the majority of cases they have only proved a source of trouble and the extra degree of flexibility which is secured by the complete belt drive has justified itself in practice by reducing the upkeep of the plant generally.

While on the subject of drilling motors, reference should be made to a system which has recently been advocated in the American fields. This consists of employing two changeable speed pumping motors, both driving on to a common countershaft. The change pole switches of these motors are interlocked so that the two machines are always operating with the same number of poles. The drilling operation is accomplished on the low-speed connection of the machines. One motor is considered as the main machine, and the second as an auxiliary. It will be readily understood that these two motors will share the work between them, in accordance with the relative positions of the individual controllers, and that by manipulating the two controllers a very wide speed regulation is obtainable. The graph which is given in Fig. 5 shows the speed—torque conditions which are available with this two-motor equipment.

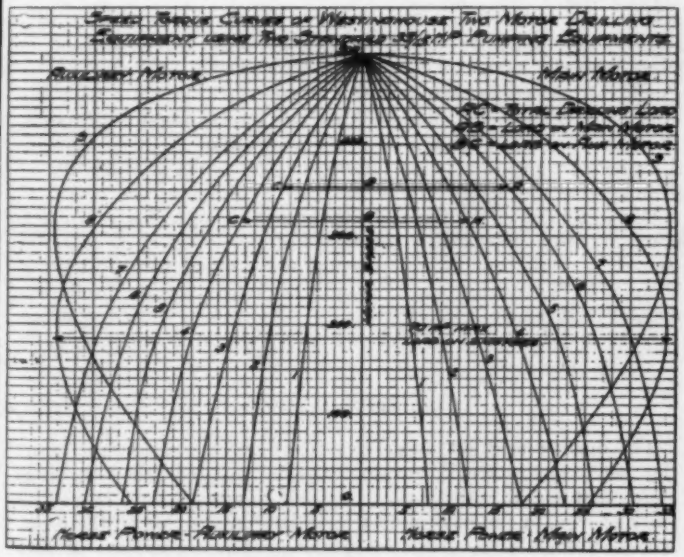


FIG. 5.

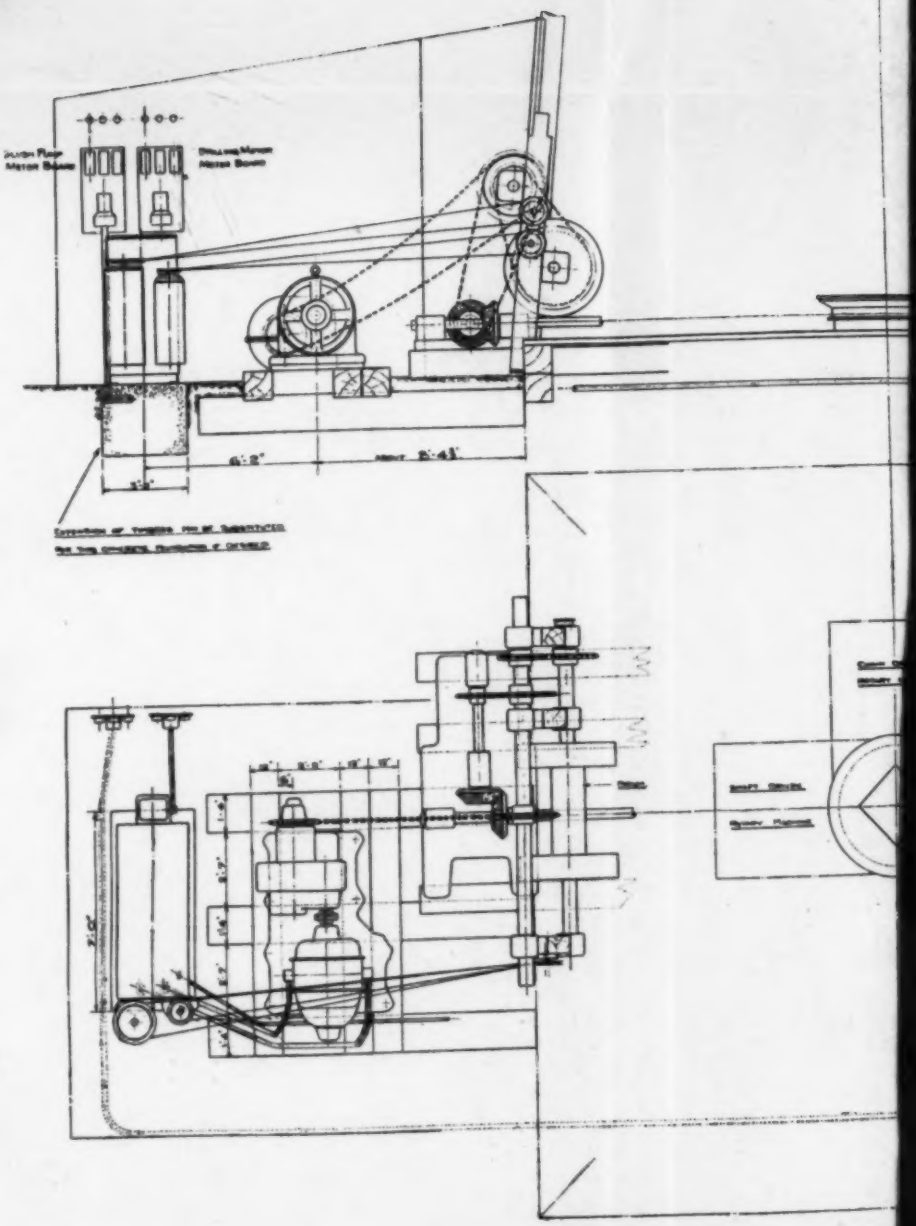
The main advantage claimed for this type of drilling equipment is the fact that when the well is completed it is only necessary to remove one machine, the second being retained together with the countershaft for the subsequent pumping duty of the well. Contrasted with the single motor system the chief objection appears to be the fact that it involves two motor foundations, two motor belts, and a much heavier design of countershaft with outboard bearing.

Where exception has been taken to drilling by electricity it can in most cases be traced finally to prejudice. The driller is admittedly a type of man very reluctant to abandon any system with which he is familiar and which has served him well in the past, and, one may add, not always receptive of new ideas, so that there has been a considerable amount of prejudice to fight against in this quarter. Unbiased opinion, however, must admit the success of the more recent system. In the Burma Fields practically no difficulty has been experienced in getting the driller to accommodate himself to this new method of operation. Men who have never even seen an electrical drilling equipment before have proved quite capable of handling it after a few days' instruction. Moreover, in Burma most of the routine drilling operations are in reality in the hands of native Burmese workmen, the European or American driller only acting in a supervisory capacity. If there had been any genuine difficulty therefore with a motor drive, one would have expected it to develop with labour of this class, instead of which the native has handled the electrical equipments with the same ease as the steam engine with which he was familiar formerly. Practical testimony and actual demonstration of this nature is sufficient to dispose of any argument that alleges difficulty of drilling with this plant.

For wells not exceeding a depth of 3500 ft. a motor of 75 h.p. nominal capacity is usually sufficient, but the design of the machine should be such that it will provide an overload torque not less than 1700 lbs. acting at 1 ft. radius. Where deeper wells are encountered, and in some exceptional formations, it is even necessary to install more powerful machines than indicated above.

Rotary Plant.

The operation of rotary drilling plant differs considerably from the percussion system, but in essential features the electrical equipment remains the same. Instead, however, of a belt drive the motor is, in the most recent installations, coupled to the draw-works through single reduction gearing. These gears are of very substantial construction and run in an oil bath. The pinion is



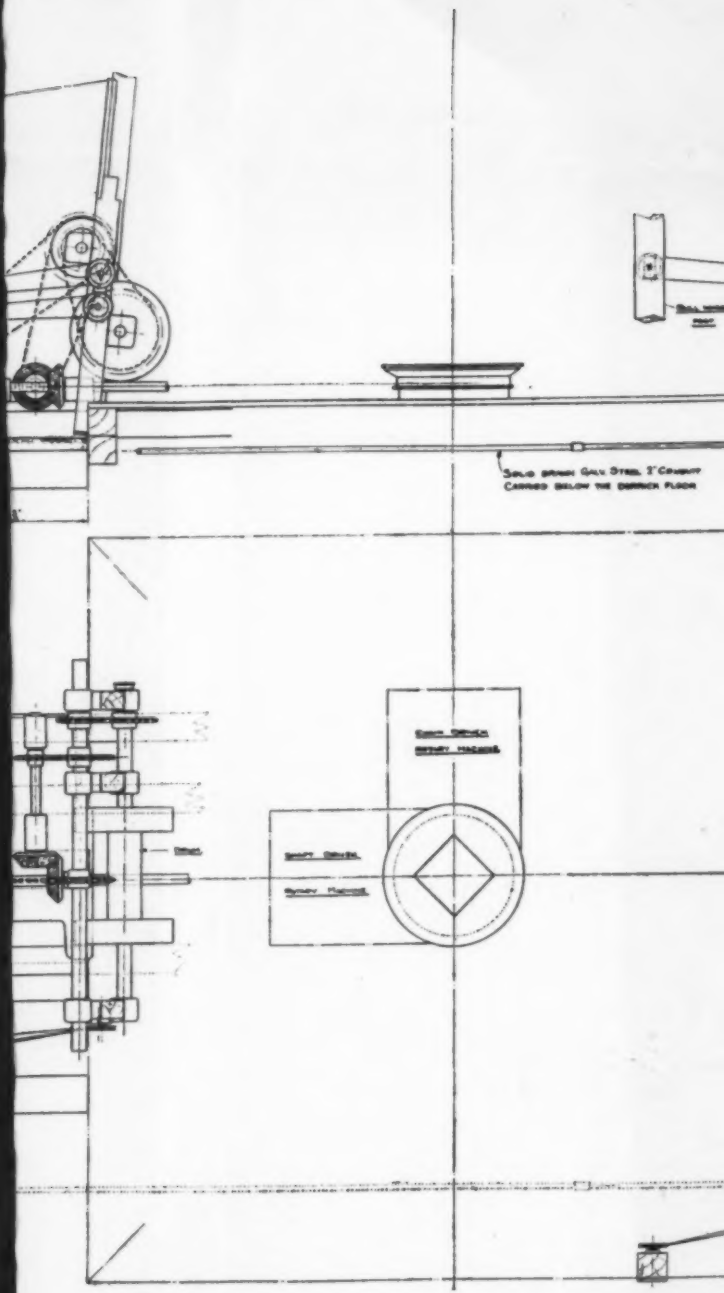
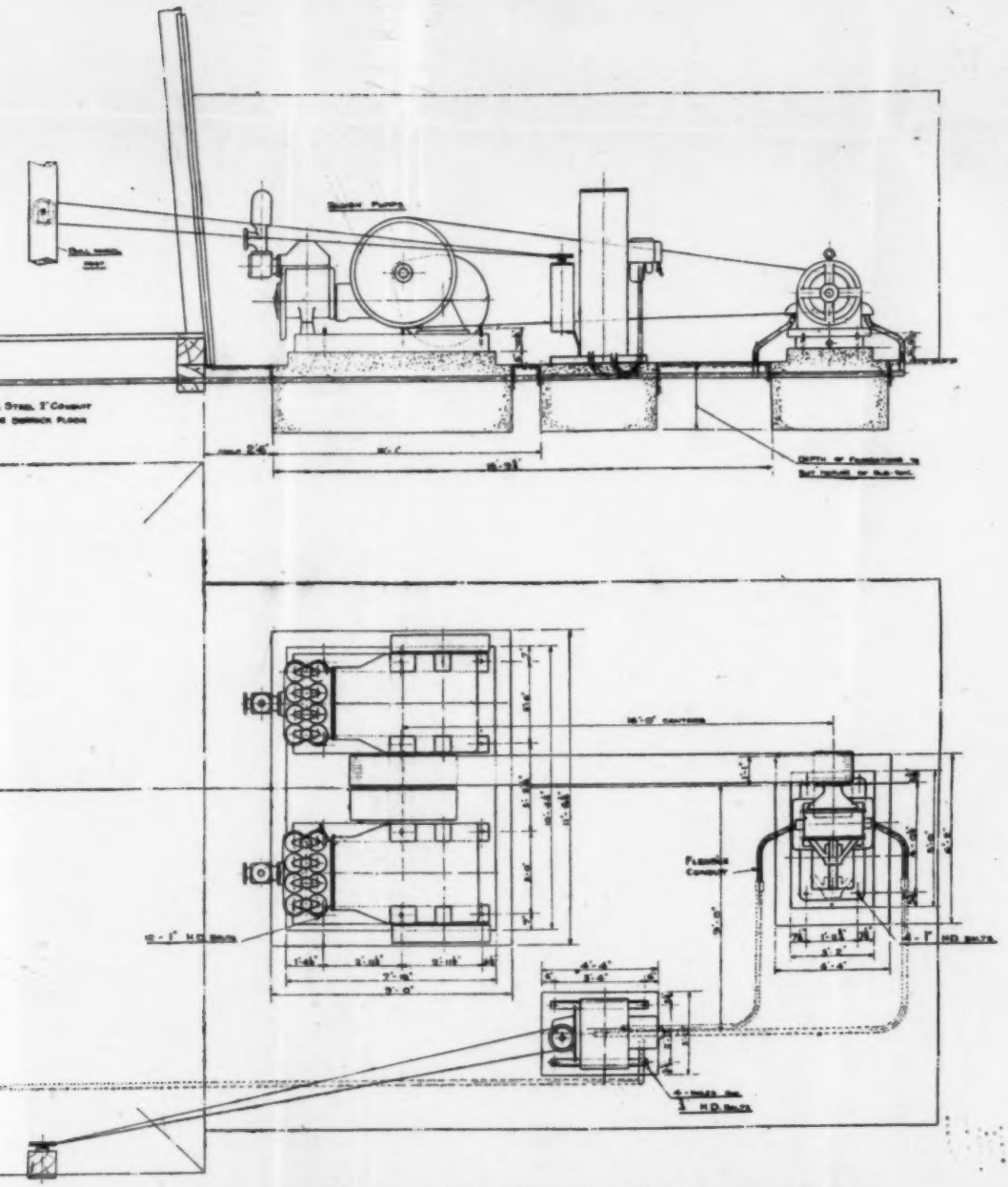


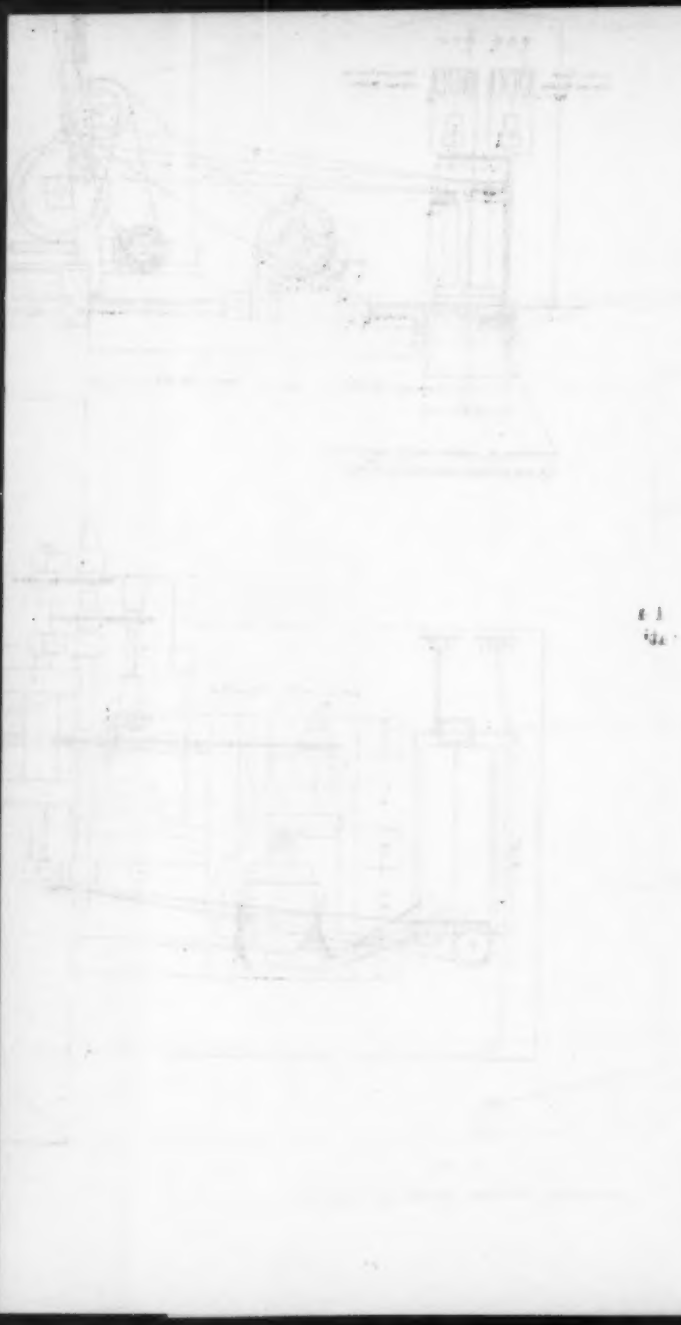
FIG. 6.

ELECTRIC DRIVE FOR ROTARY DR



G. 6.
R ROTARY DRILLING.

M/Order 3164. Simplex Conduits, Ltd. Conduit for slush pump equipment.
M/Order 3161. Callenders Cable and Construction Co. Cable for slush pump equipment.
M/Order 3146. I.G.E. Co. Flexible Conduit for slush pump motors.



made of chrome vanadium gear steel, and the gear wheel of cast steel accurately cut, pressed and keyed to the shaft. The whole gear is provided with an oil-tight cover so that it is oil and dirt proof, and the base of the gear extended so that the electric motor is bolted direct to it. The motor and gear thus form one unit, which is in turn bolted securely to the derrick timbers. A flexible coupling is used between the motor and the pinion shaft. The gear is fitted with a chain sprocket, the drive on to the draw-works being effected by a chain in the customary manner. This electrical unit takes the place of the twin cylinder engine now usually employed, the operation of the rotary being unchanged in other respects. A combination of this description is shown in Fig. 6.

The control of the motor is effected from a hand-wheel on the draw-works, or any other convenient location on the derrick floor. Control apparatus is similar to that employed with the cable tool system, and the same wide speed range should preferably be provided, so as to make the outfit suitable for the use of rock bits of the Hughes or Reed type, or for finishing the wells by means of cable tools as is sometimes done. Incidentally it has been found in practice that the continual "plugging" of a motor operating Rotary Gear is too severe on the ordinary controller reversing contacts. In the latest equipments, therefore, the actual reversing is accomplished by means of contactors, which are mounted separately, but which are automatically controlled by the movement of the controller wheel.

Provided the drilling speed of the rotary is limited to a maximum of 85 revolutions per minute, a 75 h.-p. motor will deal with all the usual requirements of a rotary rig. There are disadvantages in increasing the power above this figure, the chief of which is that with a larger motor it is difficult to obtain the speed regulation necessary on the lighter loads, and also there is more liability of twisting the tools off. The horse power absorbed in a rotary depends mainly on how the driller holds the bit off bottom, rather than the formation or size of the hole, but if speeds in excess of 85 r.p.m. are required, then it may be found desirable to increase the horse-power of the motor above the figure mentioned.

With an electrically operated rotary equipment the slush pumps are naturally electrically driven also. It is usual to employ two pumps, either of which can be driven from the same motor. This arrangement is effected by providing the motor with a sliding base so that the belt driving the pumps can be shifted at short notice from one to the other. A 50 h.-p. slip-ring motor is usually provided for this duty, and should be equipped with control and speed regulating gear similar in design to that used for the main

drilling motor, except that the same fine speed control is unnecessary.

One cannot leave the subject of electrically operated Rotary Rigs without a passing reference to the Hild Universal System now undergoing tests in the Californian field. The principle of this ingenious combination is shown diagrammatically in Fig. 7,

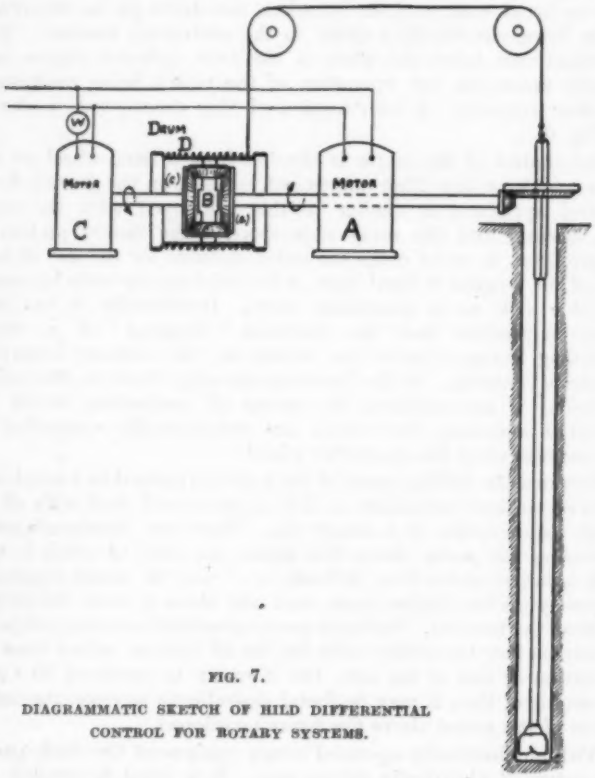


FIG. 7.

DIAGRAMMATIC SKETCH OF HILD DIFFERENTIAL CONTROL FOR ROTARY SYSTEMS.

and is explained very clearly in the maker's own words as follows :—

"The two bevel gears (*a*) and (*c*) of the differential gear set are driven by Motors *A* and *C* respectively. The differential member *B* is connected to drive drum *D*.

D is the hoist drum of the rotary works and is connected by rope to the drill pipe. Motor *A* drives the rotary table and thereby rotates the drill pipe.

Consider first the differential gear set alone and by itself.

When (*a*) and (*c*) revolve in the *same* direction at equal speeds *B* revolves in the same direction at the same speed.

When the speed of either (*a*) or (*c*) is changed, then *B* rotate, at the average of the two speeds; so that when one bevel is stationary *B* rotates at half the speed of the other.

When (*a*) and (*c*) rotate in *opposite* direction at equal speed, *B* is stationary.

When (*a*) and (*c*) rotate oppositely at different speeds, then *B* will rotate in the direction of the greater speed and at half the *difference* in their speeds.

Thus the two Motors *A* and *C* may run at or near full speed, and by varying the speed of one or the other slightly, the drum *D* can be rotated forward or backward very slowly.

Motor *A* drives (*a*) in the direction of lowering the drill pipe. Motor *C* drives (*c*) in the opposite direction to hoist it. When the brake on *D* is set, *B* is stationary and the two motors are at equal speed.

When the brake is free, the weight of the drill-pipe pulling on *D* exerts a torque on *B*, through the gearing to motors *A* and *C*. This will tend to drive Motor *A* faster as a generator. Motor *C* will oppose this pull and carry the load as a motor; it will therefore slow down somewhat.

Motor *C* takes energy from the supply circuit, Motor *A* as a generator returns it. Apart from the losses, *C* and *A* balance. The kinetic energy of the drill pipe in thus lowering itself will be transmitted to help turn the rotary table.

The work of Motor *C* is always that of raising the drill out of the hole, even when it is descending. Its load, therefore, is the torque caused by the weight multiplied by the speed of *D* if *A* were stationary. That is, the power load on *C* is always the measure of the weight on the derrick hook.

When the bit is on the bottom, the weight on the hook is diminished by exactly the amount of the weight carried by the bit. That is, the load on *C* is diminished in exactly this proportion, as the load on *C* lessens its speed increases.

A wattmeter in the circuit of *C* will thus give the measure of the pressure or weight on the bit. A differential pressure meter, embodying the wattmeter principle and calibrated in pounds, will read directly the pull of the rope to Drum *D*.

Meanwhile, when the bit presses on bottom, motor *A* rotating

it receives load due to the bit cutting on bottom. *A*, therefore, becomes a motor and tends to slow down.

The effect of *C* speeding up and *A* slowing down is to slow down the movement of *D*, that is, the drilling bit moves downward more slowly. Thus its progress is regulated by the pressure of the bit on bottom and by the load on the drilling motor. But the load on the drilling motor depends upon the pressure of the bit on the material it is cutting.

The pressure on a given material will be constant and will be proportional to its hardness. Thus the tool will advance continuously through the different formations at rates of downward movement inversely proportional to the resistance offered by the formations to the rotation of the tool.

By slightly adjusting the motor speeds, a limiting pressure or weight on the tool results. When this is fixed for the hardest material, it can be set :—

(*a*) To keep the drill stem straight ; or

(*b*) To keep the torsional stress on the drill-pipe or the load on the machinery within a predetermined value ; or

(*c*) To limit the pressure on the cutting tool so as to secure maximum cutting action ; or

(*d*) To secure the maximum all-round results by the proper combination of (*a*), (*b*) and (*c*).

When the adjustment is made for the hardest material, all other materials being softer and offering less resistance will automatically cause less stresses, less loads, less pressures on the drilling plant.

The regenerative characteristic of the drilling motor *A*, when the drill bit is descending freely or through soft materials, automatically limits the overspeed of that motor. This, combined with the continuous hoisting action of the regulating motor *C*, causes automatic limitation of the rate of downward movement of the drill tool.

This can be controlled by slightly adjusting the motor speeds, so that in gumbo or in gaseous formations the advance of the tool can be regulated and maintained to small fractions of an inch per revolution."

It is too early to say yet whether this radical innovation for rotary tool work will prove successful, because it is only in its experimental stage at present. It certainly has some very attractive features, and the automatic control which it offers would eliminate many of the troubles which are inherent to the operation of rotary drills.

PERFORMANCE.

Speaking generally, it will be found that electrical plant enables better time to be made than with steam drilling. This is mainly due to the fact that the electrical energy is always available, and there is none of the delays which are liable to occur with the portable steam raising outfits. The great superiority exists, however, in the economy effected. Two charts are attached to illustrate the performance of electrical drilling equipments.

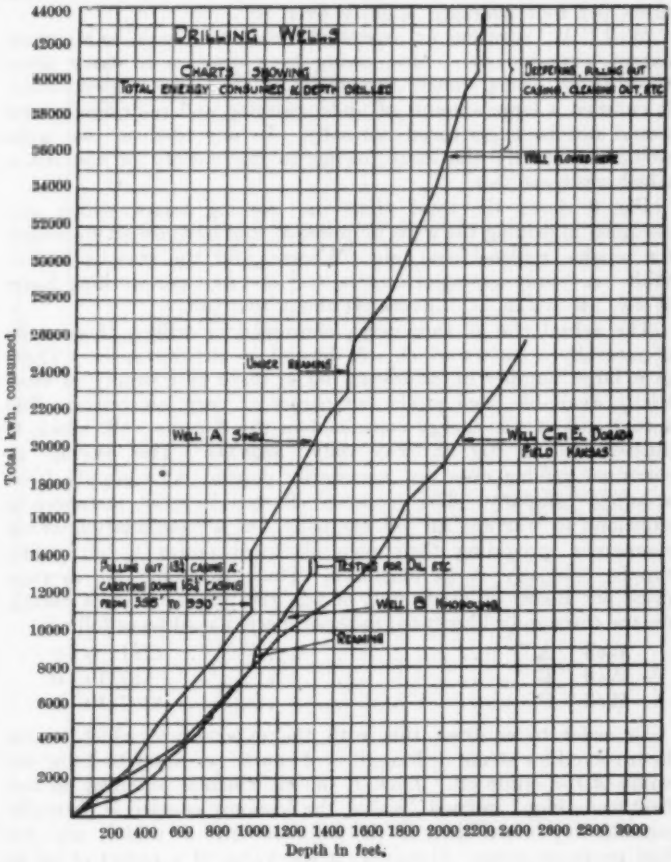

DRILLING WELLS
CHART SHOWING
TOTAL ENERGY CONSUMED & DEPTH DRILLED
DEEPENING, PULLING OUT CASING, CLEANING OUT, ETC
WELL CLOSED HERE
UNDER REAMING
WELL A SHELL
WELL CIN EL DORADO FIELD KANSAS
PULLING OUT 10" CASING & CARRYING DOWN 8½" CASING FROM 325' TO 330'
TESTING FOR OIL ETC
WELL B MIDDLEMIST
REAMING
Total kwh. consumed.
Depth in feet.
44000 42000 40000 38000 36000 34000 32000 30000 28000 26000 24000 22000 20000 18000 16000 14000 12000 10000 8000 6000 4000 2000
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000

FIG. 8.

Fig. 8 shows the total kilowatt power consumption in the case of three typical wells, two of which are in Burma, and the third in the El Dorado Fields, Kansas, U.S.A.

It will be observed from this chart that in the case of the Well " A," which was carried to a total depth of 2165 feet, the energy consumed was about 20 Board of Trade units per foot of depth. In the case of Well " B," carried to a total depth of 1270 feet, the Board of Trade units per foot were about 11, and in the case of Well " C," taken to a total depth of 2440 feet, the Board of Trade units per foot averaged slightly over 10.

Well " A " is rather an exceptional case, as it was, to a certain extent, experimental. Also, owing to a decision to carry down the 16¼ in. casing much further than originally contemplated, it entailed a large amount of under-reaming and re-drilling which would not be experienced normally. In any case no two wells would be exactly the same, owing to the variety of conditions which are to be met.

Fig. 9 shows the total time, in working hours, which was occupied in drilling the wells in question, and includes all stoppages for repairs, replacements, etc. Whereas, for the reasons stated, Well " A " only averaged a little over one foot per working hour, Wells " B " and " C " averaged about two feet.

The actual cost of the energy consumed in drilling these wells is naturally a matter which will depend on circumstances. Thus, in a large number of American fields, there is a supply of electricity available from public companies at very low prices. The actual cost of the energy consumed in the Kansas well, which is illustrated on Fig. 9, was only $348.00. The saving in electrical drilling does not necessarily depend on a supply from a public company. The economy effected in most instances is sufficient to warrant an oil company, or a combination of oil companies, providing their own electrical power if no public supply company is in existence. Thus, assuming an average price per Board of Trade unit of 1d., the relative cost of energy for the three wells illustrated in these charts would be as follows :—

Well " A "	..	..	..	..	..	£181	0	0
Well " B "	..	..	..	..	..	£57	10	0
Well " C "	..	..	..	..	..	£107	10	0

In order to contrast this with the expenditure which would be involved for steam drilling, it is of course necessary to know the value of the crude oil. Thus, if the oil which is obtained on any field has a high " refined " value, the economy effected is naturally considerably more than if the oil recovered is useful, say, for fuel purposes alone. However, if the value of a barrel of oil to the oil company is taken at the very moderate figure of 10s.,

after it has been refined and separated into the various marketable products, we shall find an extraordinary contrast in the cost of drilling the wells in question. Thus, on the basis of only six barrels of oil per working day for a steam engine, we find that the value of the oil consumed for Wells "A," "B" and "C" would be as follows:—

Well "A"	..	..	..	..	..	£550	0	0
Well "B"	..	..	..	..	..	£200	0	0
Well "C"	..	..	..	..	..	£360	0	0

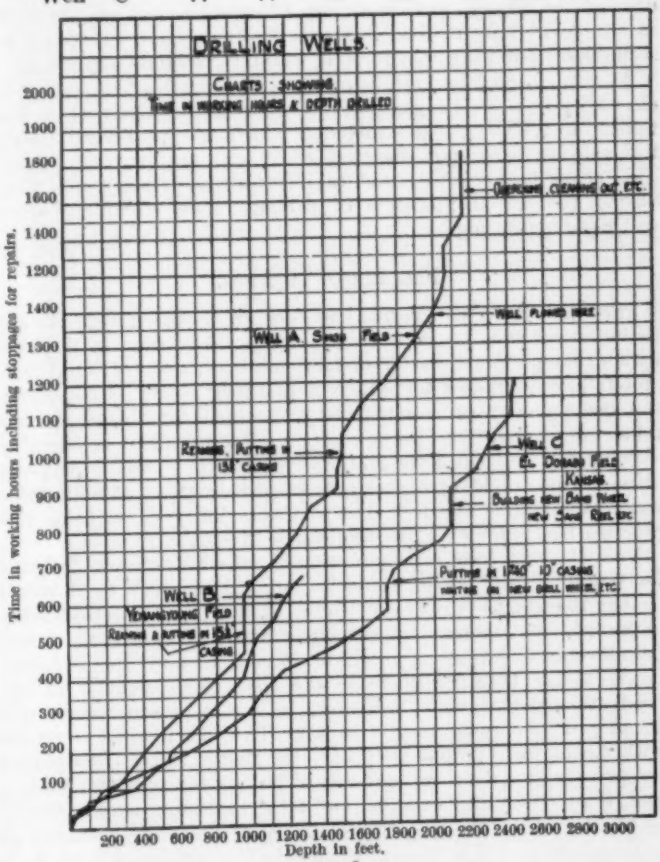


FIG. 9.

DRILLING WELLS.

CHARTS SHOWING TIME IN WORKING HOURS AND DEPTH DRILLED.

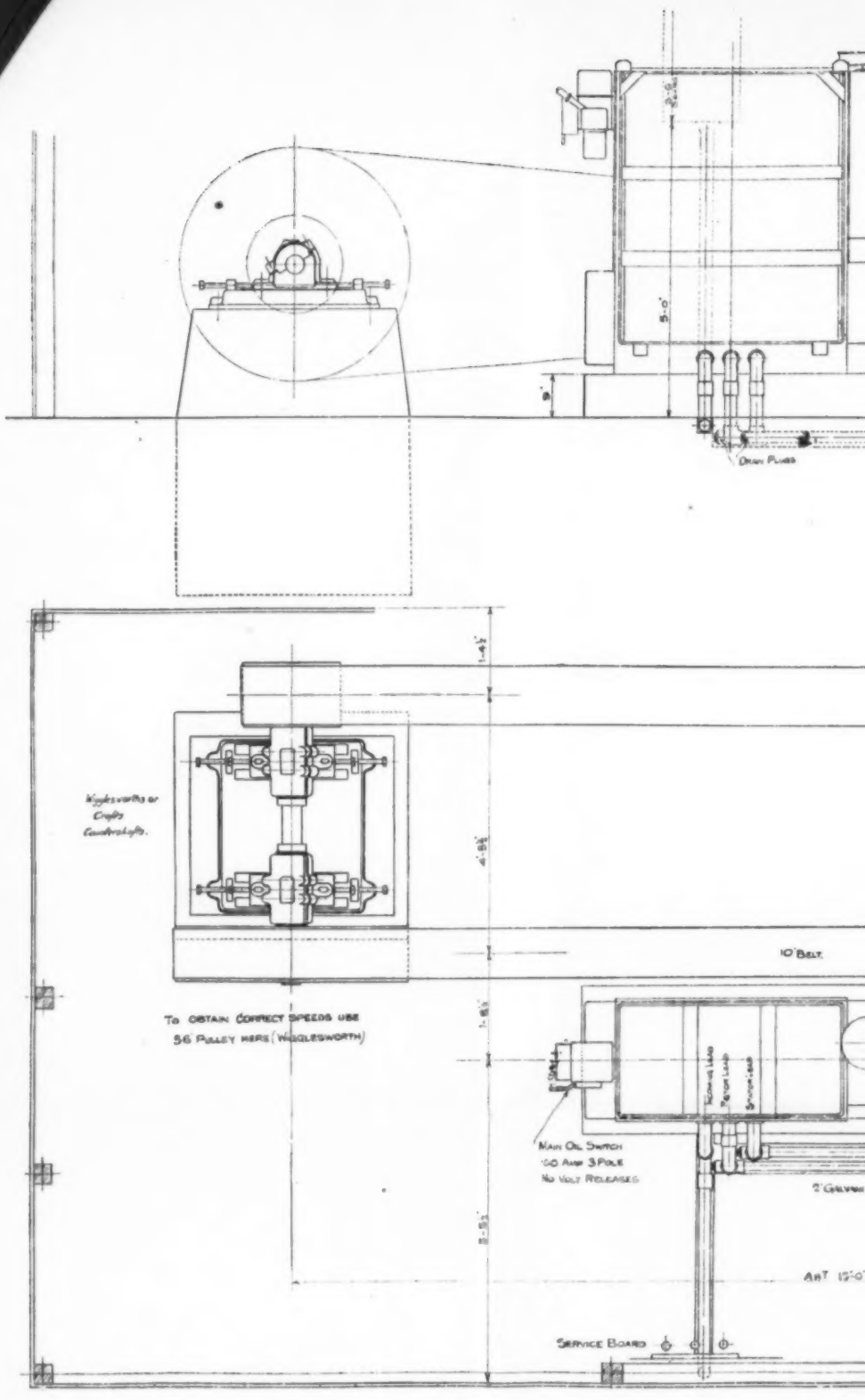
These figures show that, as far as the energy consumption is concerned, the electrical drilling on this basis only costs about 30 per cent. of the steam drilling, quite apart from the very material saving which is effected in grease, lubricating oil and by the total elimination of boiler plant and attendants. Moreover, the depreciation on the electrical motor is very much lower than it is on the steam engine. The fact that it has no reciprocating parts, and the only wear which occurs is in the journals means that the average electrical motor is in as fit condition to start drilling the second well as it was when it started on the first. It is not yet fully realised how great is the economy that can be secured by adopting this form of plant for drilling purposes.

As a matter of interest in connection with this application of electricity to oil field work, portions of a recording chart which was taken on Well "A" are included which illustrate very clearly the varying nature of the load which the drilling well entails. This chart has been selected to illustrate the energy consumed during the actual processes of drilling, under-reaming, bailing and handling casing.

Electrical Pumping.

The application of electrical motors for pumping work is apt to be considered a somewhat simpler problem than is the case with drilling. As a matter of fact, however, due to the variety of auxiliary purposes for which a pumping motor is employed, the development of a satisfactory machine for this work has taken longer than the drilling motor itself. It would considerably simplify the problem if the motor were used for pumping purposes alone. This would of course entail separate plant of a portable nature for pulling the well, but in the majority of oil fields this practice has not met with very much favour.

Viewed solely from an engineering standpoint a motor designed for pumping duty alone would be more satisfactory, as it would enable the efficiency of the whole system to be considerably improved, and, where alternating current is employed, would permit one to utilise a machine having a very much better power factor than is otherwise the case. The demand of the production departments, however, is for a motor which will accomplish the same results as they have been able to secure with steam plant; that is to say, the motor which is employed for pumping must be also capable of pulling the rods and tubing, and, if necessary, for cleaning and light re-drilling work. Owing to the fact that the majority of pumping wells are actuated at a comparatively low speed, whereas when pulling a well it is necessary to operate at high speed in order to reduce the time


Drain Plugs
10' Belt.
To obtain correct speeds use
56 Pulley Mrs (Wigglesworth)
Main Oil Switch
100 Amp 3 Pole
No Volt Releases
Service Board

30/12 H.P.

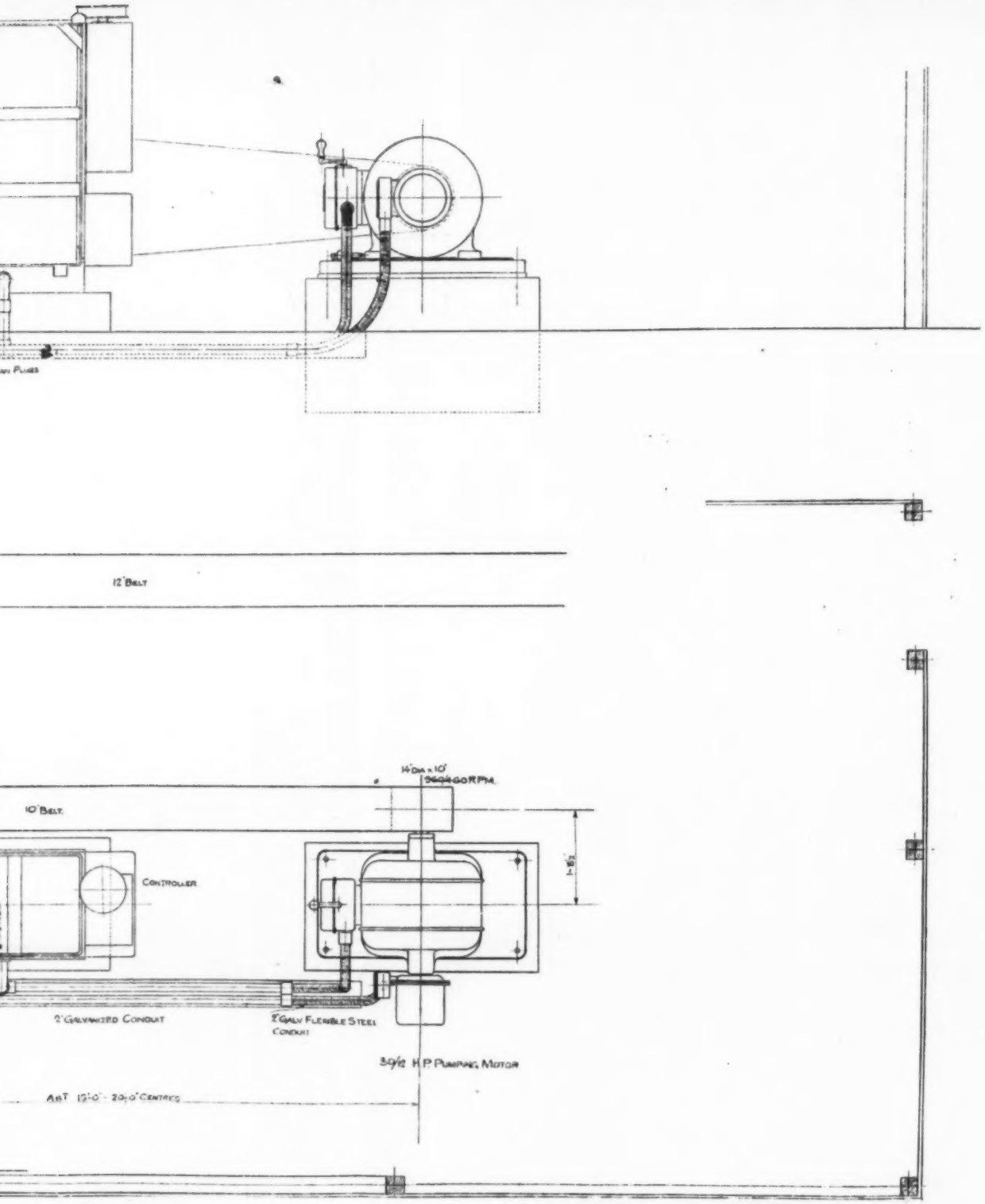


FIG. 10.

30/12 H.P. PUMPING EQUIPMENT.

	Order No.	Description.
I.G.E. Co.	M/2379	200-30/12 h.p. 960/460 r.p.m.
Crofts	M/2487	40 Countershafts and pulleys
"	M/2630	
Metro-Vickers	M/2904	100-30/12 " h.p. 960/460 " r.p.m.
Crofts	M/2930	Spare pulleys
"	M/2965	100 Countershafts and pulleys
Wigglesworth	M/2976	100 " "
	M/3036	100

when the well is off the beam, a motor suitable for this work must have two distinct characteristics. In the first place, it must be capable of supplying the small horse power required for pumping purposes with a reasonable efficiency when operating at a low speed; and in the second place, it must be capable of giving many times its ordinary pumping load output at a very enhanced speed for dealing with the other duties.

The most successful machine which has been developed for this work is a two-speed motor, so arranged that by means of a switch mounted on its frame it can be run at low speed and small output for the ordinary pumping duties, and, by changing the switch over, at high speed and high output for the other work. Whether the motor operates on the high or low speed connection it must be capable of speed regulation over a considerable range, though the same fine gradations in speed that are necessary in the drilling machine are not essential in this case.

The horse-power which is taken for a pumping well varies according to the depth of the well, the specific gravity of the oil, the number of strokes per minute which it makes, and the square of the diameter of the tubing.

In actual practice it is found that individual pumping wells require from about 3 h.-p. to as much as 17 h.-p. in certain exceptional instances. On an average, however, it may be said that a pumping well operating from the beam requires from 4/6 h.-p. when employed on pumping duty, and anything up to 50 h.-p. for auxiliary purposes.

In practice the most suitable size of motor for pumping equipments of this description has proved a machine capable of an output of 12/15 h.-p. when running on the low speed and 30 h.-p. when running on the high speed connection. A somewhat smaller motor would, in many instances, suffice for shallow wells, but the tendency of modern practice is to standardise the more powerful machine, particularly if there is any prospect of the well being carried deeper, or it is intended to use the same motor for pumping and light re-drilling work.

These motors are designed to give an overload torque considerably in excess of the normal full-load rating. Thus, a 30/12 h.-p. machine should be capable of exerting a torque not less than 625 lbs. acting at one foot radius when running on the high speed connection.

The drawing which is shown in Fig. 10 is a two-speed pumping motor as described above, complete with its control gear. It will be observed that the general arrangement of these motors is similar to that of the drilling motors; the control is operated from the headache post in the same manner and the

same form of belt drive adopted. In practice it is preferable to employ the same countershaft for drilling and pumping purposes. This means that when a well has been carried down to a productive oil-sand, the drilling motor is removed and a pumping machine substituted in its place, no other change being necessary beyond the modification in the foundation for the somewhat smaller pumping motor. Figs. 11 and 12 show an inside and outside view of an installation of this description.

On the American fields the supply available is almost universally alternating current, three-phase, 60 cycles, and the precise rating of the machines therefore is 15 h.-p. at a synchronous speed of 600 r.p.m., and 30 h.-p. when running at 1200 r.p.m. Where a 50 cycle system is available the rating is 12/15 h.-p. at 500 r.p.m. and 30 h.-p. at 1000 r.p.m. A synchronous speed higher than 500 r.p.m. or 600 r.p.m., is not desirable for ordinary pumping purposes, as it would render it somewhat difficult to effect the reduction necessary in order to get the correct bandwheel speed. Although the control gear for these machines is designed for varying the speed and capable of running continuously on any point, it is desirable to arrange the ratio of the drive between motor and countershaft and between countershaft and bandwheel, so that only a small portion of the motor resistance remains permanently in circuit when the machine is on pumping duty. If a large proportion of the resistance is left in circuit it reduces the capacity of the motor and makes the operation less economical than is otherwise the case.

The latest pumping equipments have provision made for locking the change-over switch so that no unauthorised person can throw the switch over from the high speed connection to low speed or *vice versa*. Similar provision is made on the controller to prevent any change in the pumping speed of the walking beam once the most suitable number of strokes has been determined. These precautions are found particularly valuable where plant is in the hands of native labour whose discretion cannot always be trusted in details of this nature.

The advantages secured by electrical pumping can be summarised as follows :—

1. The great economy in fuel effected as compared with steam engine plant.
2. The steady unvarying output. Once the motor is put into operation there is no variation in speed, whereas with steam plant, as soon as the boiler pressure drops, so does the speed of the engine. The increase in output due to the perfectly constant and reliable motion secured with electrical operation has been found to be as high as 26 per cent. in certain cases.

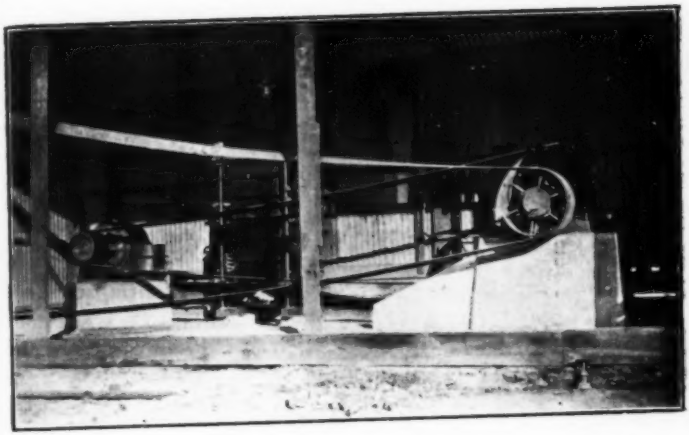


FIG. 11.
PUMPING INSTALLATION (INTERIOR VIEW).

FIG. 12.
PUMPING INSTALLATION (EXTERIOR VIEW).

3. The lower labour charges. One attendant can look after as many as 15 to 20 pumping equipments, whereas with either steam or gas engine drive a very much larger number of attendants is necessary.
4. The decreased cost of lubricating oil, waste, etc. As the motor lubrication is automatic motors will run for weeks without any change of oil, whereas, with either gas engine or steam drive, the quantity of oil for lubrication, etc., is a serious item.
5. The low maintenance costs. The life of a pumping motor, with ordinary reasonable care and attention, may be anything from 15 to 20 years.
6. Reduction in shut-downs due to engine troubles, rod breakages, choked steam-lines, etc.

An average 24-hour pumping well will take something like 3,000 Board of Trade units in a month; this figure of course varies according to the well; it may be considerably more in some cases and less in others. 3,000 units at the price of 1d. per unit is £12 10s. per month. The steam-operated pumping well, working the same number of hours, will take at least three barrels of oil per day, and very often averages more. Allowing a figure of 10s. per barrel as before, this is equivalent to £45 per month. The discrepancy between these two figures is striking, but it will be found on analysis to hold good generally where steam is employed for pumping purposes. A more general comparison between steam and electrical pumping is supplied by the curves on Fig. 13. These curves contrast the cost of pumping small producing wells operating 24 hours a day by steam and alternatively by electricity. Curve A is based on an average expenditure of three barrels of oil per well per 24 hours. Curve B for the electrical operation is an actual average over a number of small producers of this description. The value of the crude oil is taken at 10s. per barrel, and the relative value of a B.O.T. unit delivered at the motor 1 penny. An average of three barrels of oil per pumping well per 24 hours is an assumption which errs on the low side. There are so many variable factors in the operation of these wells that the curves can only be looked on as affording an approximate idea of the relative cost of energy per barrel with the two systems. Thus any given point on curve B represents an average, and individual wells may fall considerably above or below the figure indicated. Attention is drawn to the fact that even if the engine operated wells were provided with steam generated by natural gas, the relation between the curves would still remain approximately the same, because any lower value attributed to the gas fuel would cause a corresponding fall in the cost per electrical unit supplied. It is difficult to secure reliable

figures for the fuel consumption of steam engines operating wells only a few hours each day, but the contrast with electrical pumping in these circumstances would be even more markedly in favour of the electrical drive.

Where gas engines are employed it is difficult to make the same direct comparison, in view of the fact that in a number of fields the gas has no definite marketable value. If, however, it is realised that every cubic foot of gas burnt represents an equivalent quantity of oil conserved, it is not unfair to say that the value of the gas and the oil can be equated. In other words, it is misleading to

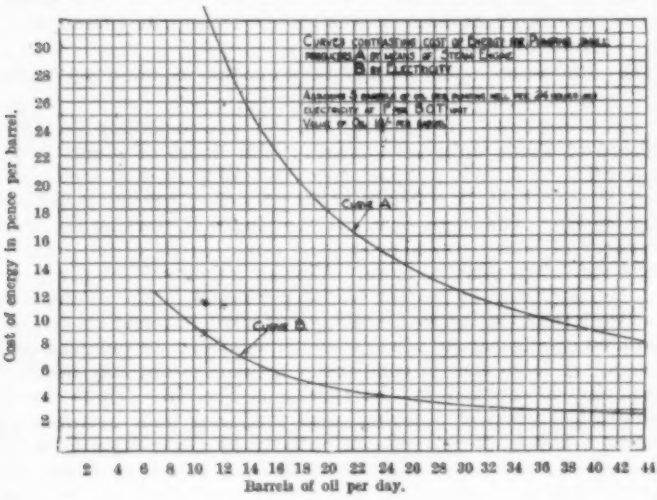


FIG. 13.

suppose that because natural gas is being used it has no intrinsic value. It has inherently the same value to the oil company as the fuel which it would be necessary to substitute for it were gas not available.

The experience which the author has gained on the Burma fields has demonstrated that if natural gas is being expended in heating individual boiler units, it is much more economical to collect this gas and burn it under a centralised high efficiency modern boiler installation.

Although there would be no difficulty in showing that on the basis of the thermal efficiency of a gas engine as compared with the best thermal efficiency obtainable from, say, modern steam turbine plant, the gas engine is the more economical unit to employ,

it by no means follows that with a combined system where gas is used both for gas engine plant and for steam boilers, you will get anything like the same overall economy as you do with a centralised power system using steam turbine plant. Moreover, when all the other aspects of the question are taken into consideration, it will be found in every instance that the motor is the more economical drive. Rod breakage alone is a very important factor. Both steam and gas engines pick up the rods with a jerk which is absent with the motor drive; the result is crystallisation and eventually breakage, which is very largely eliminated by the even turning moment which the motor provides. The motor also has the great advantage of increased flexibility and does not suffer from the very limited overload capacity which is inherent to a gas or oil engine. Furthermore, as has been indicated before, if you wish a strict comparison between gas engine drive and electrical, you must in all fairness assume the prime movers driving your electrical plant are gas engine driven also. The fundamental consideration which the author wishes to emphasise is the centralised system of power generation as contrasted with the distributed system of small individual machines.

Record of Energy Used.

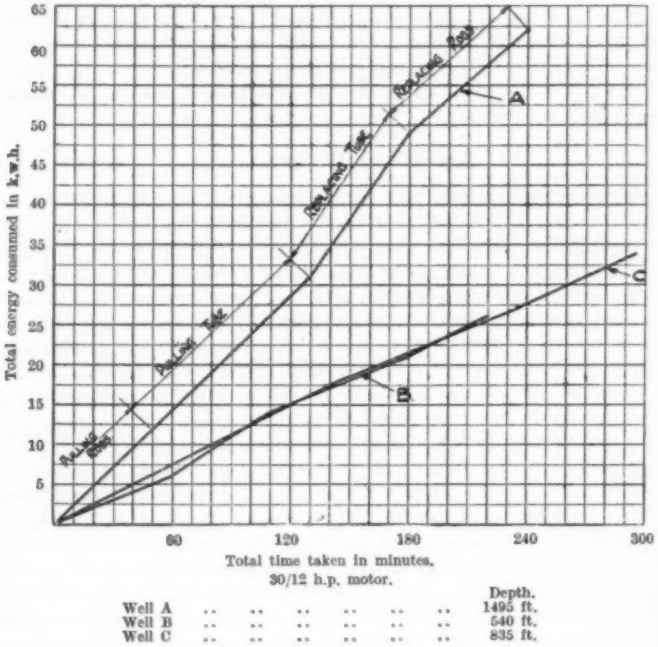
Another great advantage which electrical operation offers to any manager of an oil field is the precise information afforded regarding the efficiency with which the individual wells or units are operating. Thus, in the case of the Burmah Oil Co.'s installation, which is being described later, a recording meter is attached to each well, so that the exact consumption of energy can be measured from day to day and balanced against the production of the well in question. It is hardly necessary to emphasise the importance of this feature, and it will at once be evident that, particularly in the case of small producers, the management are in a position to judge without hesitation those wells which it is best to pump and those wells which it is preferable to abandon.

With regard to the ability of the motors to perform the auxiliary duties required, such as pulling a well or cleaning it, and light re-drilling work, the attached charts, Figs. 14 and 15, show actual results obtained with a 30/12 h.-p. pumping motor when pulling rods and tubing and rods alone. The time shown for the operation is the actual net time, which is not necessarily the same as the duration of the shut-down, which would vary according to the work required, such as changing cups, changing valves, replacing split or broken rods, etc. These same pumping motors have also been used extensively for spudding shallow wells, cleaning and deepening existing wells. The actual energy consumption under these

conditions will be governed by the particular circumstances of each case.

Auxiliary Plant.

The operation of the auxiliary plant which is employed in the winning of crude oil is so straightforward that the author does not propose to devote much time to it to-night. Where electrical power is available there is very rarely any question regarding the method of operating these auxiliaries. Thus, all oil pumping, water pumping, workshop driving, lighting, etc. is naturally accomplished electrically, with a corresponding economy in fuel, labour and stores. There are other advantages, such as cleanliness, economy in space, etc., which, if less tangible assets, must nevertheless not be overlooked.



	Depth.
Well A	1495 ft.
Well B	540 ft.
Well C	835 ft.

FIG. 14.

PUMPING WELLS.

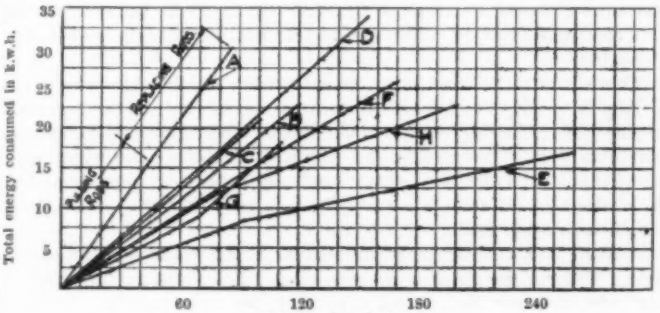
GRAPH ILLUSTRATING ENERGY CONSUMED AND TIME TAKEN IN PULLING AND REPLACING RODS AND TUBING.

Where gasoline extraction plant is provided, the experience on the American fields, in many instances, has been that it is better to drive the boosting and compressor plant by electrical motors, rather than to employ gas engines. Naturally, this is not due to any superior overall thermal efficiency, but simply because the electrical running is simpler and more reliable, and the maintenance charges are so much lower.

General Principles.

The great economy and other advantages which follow the application of electrical power having been established, it is necessary to consider how this application is best effected.

When an oil field is located within a reasonable distance of an existing supply company, generating power on a sufficiently large



30/12 h.p. motor.

	Depth.		Depth.
Well A	2468 ft.	Well E	1750 ft.
Well B	1697 ft.	Well F	1807 ft.
Well C	1500 ft.	Well G	1699 ft.
Well D	2617 ft.	Well H	1247 ft.

FIG. 15.

PUMPING WELLS.

GRAPH ILLUSTRATING ENERGY CONSUMED AND TIME TAKEN PULLING AND REPLACING RODS ONLY.

scale, the problem is considerably simplified. America has been particularly fortunate in this respect, and the application of electricity on a large number of American fields has merely involved the problem of the most suitable form of distribution and equipment to adopt. If, however, as is often the case, the oil fields are remote from civilisation, the problem of converting a field entails the provision of a power supply station, and possibly, the transmission of energy some distance. Naturally the capital expenditure

entailed if plant and buildings of this nature have to be provided is considerably greater than if the supply is already to hand. Nevertheless, the saving effected by electricity is usually so substantial that even with this additional charge, there are, in the opinion of the author, few cases where it would not pay to install the complete generating plant as well as the motors required for its application on the field.

One need hardly add that each proposal must be considered on its own merits. There are too many variable factors to enable one to lay down any hard and fast rules; thus, obviously the value of the crude oil will vary considerably, and the net saving due to lessened consumption will correspondingly vary. Again, one field may have a superabundance of natural gas of no marketable value employed exclusively in gas engines or under boiler plant. The economy obtainable in these circumstances may not look so attractive at first blush as in the case where crude oil is employed, but due investigation will usually demonstrate that it is still considerable.

There is another important consideration which arises where gas is largely used, namely, the advantage of conserving the gas as a means of lengthening the life of the field. This applies in two ways. First, the conservation of the gas increases the total yield which may be anticipated from any given sand. Secondly, it postpones the date when an exhausted gas supply may make it necessary to have recourse to other fuels.

A third factor of primary importance is the estimated life of the field. Clearly the running charges on any field must include a sinking fund to cover the capital expended, the annual value of which will vary according to circumstances. In this reference, however, it is of importance to note in passing that with electrical operation the life of the field can usually be considerably extended, for the reason that it pays to pump small producing wells to a much greater degree of exhaustion than by any other method. Whatever angle you approach the question from, however, and whatever the conditions obtaining on a field, there are very few oil fields which would not benefit materially if an electric drive were introduced.

The author finds that as a general statement, and subject to the limitations which this involves, it can be stated, without undue optimism, that by means of a concentrated electrical power scheme, as contrasted with the numerous individual separate units more usually employed, you can accomplish the same work for one-third and less the fuel consumption. This applies whatever the type of fuel consumed if any considerable proportion of it is burnt under boiler plant, and to a modified extent even with gas engine plant, so that if you take a long view it is not very material whether the existing system employs chiefly crude oil, or whether it is burning

gas, or any other fuel which may be available in the district where the oil field is situated. This fundamental economy of fuel is quite apart and distinct from the large saving effected in labour, oil, waste, stores and maintenance charges.

When you come to close quarters with the actual problem of oil fields electrification, you find a considerable difference between the conditions with which you are confronted. Thus, you may have to deal with a comparatively small field on which is concentrated a very large number of wells; or you may find one large field with wells scattered some distance apart; or, alternatively, several small concentrated fields all within a comparatively small radius. It does not necessarily follow that the most successful method of dealing with one system will be the most satisfactory for another. Thus, in the majority of the American fields, with the wells spaced a considerable distance apart, it is usually the custom to carry high tension mains through the field area, and to step down to low pressure at individual wells, or at groups of wells, as the case may be. In the case of a very concentrated field, it is preferable to distribute in the congested area by means of low tension current alone, and to keep the h.t. lines outside the active zone. A group of fields is best served by a supply from a point as closely equidistant from all the fields as is consistent with the various requirements of economical generation. Whatever the condition, however, it is a *sine qua non* that the system should be laid out so as to avoid any possibility of a breakdown affecting the continuity of supply; thus, whereas the failure of any one pumping or drilling unit under the old system has very little material effect on the production of the field, the failure of a centralised power supply might prove very serious if sufficient precautions were not adopted in this direction—in fact, one of the arguments which has been advanced against electrification is that there is lack of security in this respect. With a carefully thought-out scheme, however, the probability of any serious interruption is very remote, and it will be found in practice that more continuous and less interrupted service is provided by electricity than by the existing methods.

The next important consideration is the type of prime mover to adopt, and here it is impossible to lay down any rule without a specific scheme in front of one. Thus, if there is no lack of natural gas, gas engine-driven plant might prove the most suitable, always bearing in mind that although a field may have a large quantity of gas available at one stage of its history, it may be faced later with a condition where gas is not available.

Naturally, Diesel engine plant will also require careful consideration, but here again we are dealing with a plant which is not suitable for utilising the natural gas supply, and though the economy in oil is unquestioned, if there is no suitable residue available, you

would be consuming the valuable crude which is otherwise available for refining purposes.

Reciprocating steam engine plant would nowadays hardly be considered, except in exceptional circumstances, but there remains steam turbine plant, or water power plant. If the installation is a large one, steam turbine plant of a very economical type can be procured and is, of course, equally suitable whether you have natural gas, crude oil, residue, or any other fuel available. Water power, except in very special circumstances, always involves rather heavy capital expenditure, and if the estimated life of the field is a somewhat doubtful quantity, it would, in most instances, hardly pay to develop it, unless there were alternative sources of demand for which the power could be employed.

Among these many systems, however, there is one which is likely to be suitable for each individual case, and sufficient has been said to show that only after careful study of the conditions, can any decision be arrived at.

Generating Costs.

The capital expenditure involved in providing a Power Station and distributing system for an oil field, or a group of oil fields, is dependent on many factors and will, of course, vary according to the nature of the field and the number of wells it contains. Furthermore, the cost per unit generated will depend, not on the capital expended alone, but on the fuel obtainable, the method of generation, and on the estimated useful life of the plant. Clearly each proposition will require a different answer, but as a general indication the author has included a curve (Fig. 16) showing the estimated

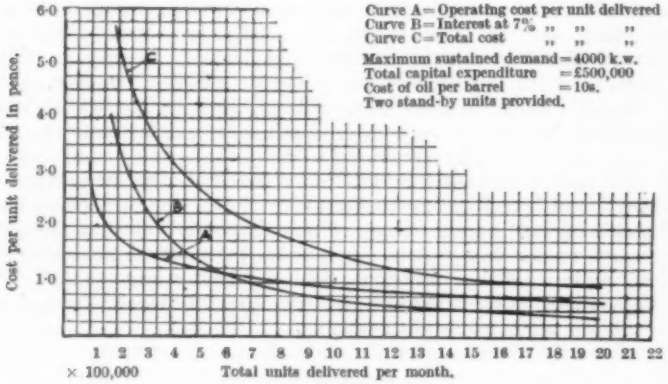

Curve A = Operating cost per unit delivered
Curve B = Interest at 7% " " "
Curve C = Total cost " " "
Maximum sustained demand = 4000 k.w.
Total capital expenditure = £500,000
Cost of oil per barrel = 10s.
Two stand-by units provided.
Cost per unit delivered in pence.
6·0
5·0
4·0
3·0
2·0
1·0
C
B
A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
× 100,000
Total units delivered per month.

FIG. 16.

APPROXIMATE COST OF POWER WITH STEAM TURBO-GENERATOR UNITS.

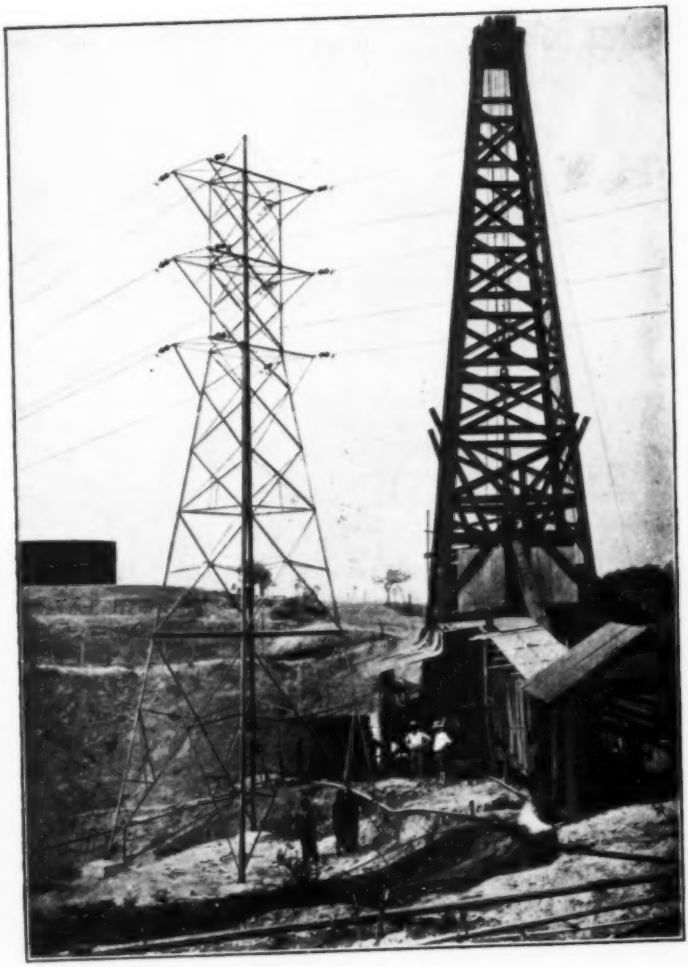


FIG. 17.

cost per unit delivered in the case of a moderate sized system employing steam driven turbo-generator units. Speaking generally, this curve would apply to a field of some 500-600 pumping wells, and assumes that all auxiliary plant would be motor driven. Oil fuel is taken as worth 10s. a barrel and 7 per cent. interest on capital expended is provided for in the costs. The total cost per unit delivered on this assumption is slightly less than 1d. If natural gas were available in place of oil fuel, and the gas had no market value, this figure of 1d. could, of course, be considerably reduced, according to the value which was placed on the gas in question. It must never be overlooked when comparing the respective advantages of electrical driving with other systems that even if a plentiful gas supply is available, it will ultimately be of the greatest importance to the oil companies to conserve this gas and use it as economically as possible.

The Yenangyoung Installation.

These foregoing general remarks bring the author to the stage where it will be valuable to describe the scope and methods adopted by the Burmah Oil Co. in their Yenangyoung scheme.

The Yenangyoung field has, as is generally known, proved one of the most prolific oil bearing territories for its size in the world, and has suffered, in common with other fields, from relatively uneconomical methods in the past. The conversion of all wells to electrical drive was first studied in 1910. At that date—in this field as unhappily still to-day in a number of the oil fields of the world—the pumping and drilling plant consisted in the main of some hundreds of small relatively inefficient steam, and to some extent gas, engines, the steam engine being supplied with steam from numerous portable boilers burning crude oil fuel, and alternatively, natural gas. The steam piping was also often of considerable length. It needs no figures to demonstrate how wasteful this system was. The important economies and valuable conservation of oil which could be effected by replacing these small steam units by central station plant, designed on modern lines, are apparent.

A small trial electrical installation was supplied to the Burmah Oil Co., in 1914, and the results, both with drilling and pumping equipments, were so satisfactory, that the Directors decided on the bold course of converting the whole of their wells and auxiliary plant in the Yenangyoung field to electrical operation. This important project was held up due to the outbreak of war, but as soon as peace was re-established, matters were put in train and the scheme was successfully inaugurated in August 1922.

The Yenangyoung oil field is situated on the east bank of the

river Irrawaddy, approximately 300 miles from its mouth. The area of the field actively producing is only two-and-a-half miles long by half-a-mile in width. In this area there are, at the present time, approximately 1000 wells belonging to various Oil Companies, a number of workshops, auxiliary pumping plants and the miscellaneous apparatus attendant on any large industrial scheme.

The question of the best type of prime mover to adopt for the operation of this field received careful consideration. In view of the large amount of power required gas engine units of very large output would have been necessary. Moreover, there was no certainty that the field would be capable of supplying the gas required during its estimated life. Diesel engine plant would, of course, not have been suitable for using the gas which was available and would have committed the Company to a policy of consuming crude or topped oil, as no residue was available. For these and various other reasons it was ultimately decided to supply steam turbine plant, and a Power Station was erected about two-and-a-half miles distant from the field, in close proximity to the river.

Engine Room and Annexe.

The Engine-room and Switchgear Annexe is a steel structure filled in with concrete blocks.

The Station is equipped with four—4000kw., 6150 kva. three-phase, 50 cycle turbo-generator units generating at 3300 volts, and four kva. oil-cooled Transformers for stepping up the machine pressure to 13,200 volts. The Transformers are placed in separate compartments and are tied to the machine terminals without the intervention of any switchgear, so that each turbo-generator and transformer form virtually one unit. The 13,200 volt terminals of the transformer are coupled to switches mounted in moulded stone cubicles built in an annexe of the engine-room. The switchgear is arranged in two tiers ; on the first floor the cubicles contain the h.t. switching apparatus, current and potential transformers ; and on the second floor, the busbar chambers, busbar isolating switches, etc. The board is arranged with duplicate busbars, each set of busbars being carried in its own separate compartment. All the switches are electrically operated from a control board of the usual bench-board design, which is situated on the second floor overlooking the engine-room.

There are two—13,200 volt outgoing feeders for the supply of energy to the oil field, each of the overhead split conductor type. In addition, duplicate outgoing H.T. feeders of the plain type, which supply the local requirements of the Burmah Oil Co., at Nyaunghla, including the main line oil pumps. Provision is also

made for additional feeders of the same description should the developments of the scheme in the future require it. All outgoing overhead feeders are protected by oxide film lightning arresters, and are carried through the roof of the annexe building by means of special porcelain roof bushings. The conductors are carried from these bushings to a specially designed steel roof structure, and from thence to the various transmission line towers.

The split conductor system of transmission to the fields was adopted as particularly suitable to oil field conditions where continuity of supply is of paramount importance. For the benefit of those who are not familiar with the system it may be described briefly as follows:—Each overhead conductor is split into two wires of equal resistance. With a healthy overhead line these two wires will therefore share the load current equally, but if either wire goes to earth, or one is broken, then the current in them becomes unbalanced. At each end of the line these two wires are connected to special current transformers, so arranged that the current flowing in the one wire exactly neutralises the current in the second wire. So long as no fault occurs in the overhead line, things are in a state of equilibrium and the only protective gear which is operative consists of the overload relays which are installed for the protection of the plant. Immediately, however, a *line* becomes faulty, the out-of-balance current in the transformers referred to brings a tripping relay into action and cuts out the line at both ends. This line protection is quite independent of any voltage fluctuations or overloads, and is so instantaneous in its action that the faulty line is cut out without any disturbance to apparatus which has an alternative source of supply. It will readily be understood therefore that where duplicate transmission lines are employed no accident to one of them can cause any interruption to the supply on the field, and if the two duplicate lines are further carried by different routes the chances of an interruption due to line troubles is extremely remote.

The turbo-generators exhaust to low level jet condensers, placed in the basement immediately below the turbines. The condenser cooling water is drawn from a culvert running between the engine-house and boiler-house. This culvert leads to a large storage and settling tank at the north end of the building. Under normal operation conditions this tank is supplied with water from the river by means of two electrically operated 14 in. centrifugal pumps, having a capacity of 5000 gallons per minute, placed in a pumping station on the river bank, and it will function mainly as a means of settling the fine deposit which is carried in suspension in the river water. Owing to the vagaries of the river, however, it may prove difficult to pump the required amount of water

during low water period, and if this contingency arises, provision has been made for utilising the tank as a spray cooling pond during such time as water is unobtainable from the river in sufficient quantity.

Boiler-house.

The boiler-house is a steel structure covered with corrugated sheets. The present plant consists of six Babcock & Wilcox land type water-tube boilers, each capable of evaporating 30,000 lbs. of steam per hour under normal duty, or 37,500 lbs. of steam under overload conditions. The boiler pressure is 200 lbs., and the steam is superheated to a total temperature of 650° F. by means of superheaters integral with the boilers.

Each boiler is provided with 12 oil fuel burners designed on the pressure atomising system, and also 12 gas burners for burning natural gas. It is anticipated that under normal working conditions the natural gas obtainable on the field will supply all the requisite fuel at the present time. This gas has a thermal value averaging nearly 1000 B.Th.U.'s per cub. ft.

Each boiler operates in conjunction with a Green's Economiser consisting of 256 tubes, and the gases from each pair of boilers are carried to a separate self-supporting steel chimney having an overall height of 150 ft. It was originally intended that each pair of boilers should be operated by means of an electrically operated induced draught fan common to them both, but experience has shown that it is an advisable precaution to isolate each boiler, and this modification is being made by introducing a second fan and dividing the chimney for a portion of its height, by means of a steel diaphragm.

The pump room contains two steam driven vertical Weir feed pumps, each capable of supplying 9000 gallons of water per hour, and one electrically operated turbine feed pump of approximately the same capacity. There are also two steam driven oil fuel pumps, each suitable for supplying oil fuel to three boilers at a pressure of 200 lbs. per sq. in., and one electrically operated pump of similar design and capacity.

Transmission Lines.

Electrical energy is conveyed to the field by means of two transmission lines, each approximately 12,500 ft. in length. The lines are conducted along separate routes, so as to avoid, as far as possible, the contingency of both being interrupted at the same time. In case of emergency either transmission line is capable of carrying the total load.

Each transmission line consists of six No. 0 B. and S. stranded wire conductors carried on galvanised steel towers. Ordinary pin type insulators are provided for the intermediate towers, but the line is anchored by means of Hewlett strain type insulators at frequent intervals. An overhead stranded steel earth wire $\frac{3}{8}$ in. in diameter is carried the whole length of the line. In order to minimise the interruptions which are liable to occur with an overhead split conductor system when birds cause a temporary earth to the cross-arms of the towers, the pin type insulators are raised considerably higher than is usual in ordinary transmission line practice. One of the anchor towers used on these lines is shown in Fig. 17.

Main Receiving Sub-Station.

The two transmission lines are run to a main receiving sub-station centrally situated on the western side of the field. This receiving station acts as a distributing centre for the whole of the oil field, and is equipped with electrically operated remote control high tension switchgear of similar design to that provided in the power station. The building is a steel and concrete structure, and it also serves as the headquarters of the Fields Electrical Engineering Staff.

H.T. Ring Mains.

The main receiving station feeds two split conductor ring mains which encircle the more active part of the oil field. These ring mains are tapped by 12 sub-stations, also confined to the outskirts of the field. Owing to the very congested nature of the oil well area, it was thought desirable to keep the entire H.T. system outside it.

The ring mains are carried across each sub-station on overhead steel structures which form a series of anchor towers. Alternate sub-stations are tapped off different ring mains, and between every sub-station split conductor protection is provided. These ring mains are carried on galvanised steel towers of identical design to the main transmission lines, except that the cross-arms are extended so as to carry a total of 12 conductors instead of six. If any fault occurs on the ring main between any two sub-stations, it results in this portion of the line being cut out automatically without interrupting the supply of energy to any of the sub-stations. Moreover, if either ring main fails in two places and thus interrupts the circuit entirely, the remaining ring main is still capable of supplying energy to all the alternate sub-stations

round the field, and by means of interlinking the low tension distributors, a supply can be maintained at every well. These usually elaborate precautions have been deemed necessary in view of the paramount importance of maintaining a supply of energy on the oil fields in all possible circumstances. Fig. 18 is a diagrammatic representation of the system of supply generally, which will make it clearer than any verbal description.

Sub-Stations.

The sub-stations are rectangular steel structures approximately 26 ft. square, with 9 in. walls of concrete block or brick. They are built with two floors. The upper floor contains the H.T. cubicle switchgear and lightning arresters, and the ground floor the L.T. switchboard and transformers.

Each sub-station has provision for two 500 KVA. three-phase transformers reducing the line pressure of 13,200 volts to 460 volts, for distribution on the field.

Low Tension Distribution.

From each sub-station radiate the low tension feeders providing actual energy to the individual wells, and to the auxiliary plant on the field. Each distribution feeder consists of six No. 0000 B. & S. stranded copper conductors carried on 35 ft. Bates expanded steel truss poles. The conductors are run two in parallel, and the length of each distribution feeder is kept as short as possible. The provision of parallel conductors and the short length of the feeder has been rendered necessary in order to reduce the reactance of the low tension system, and to provide reasonably close regulation at the motor terminals. The actual drop on each distributor under normal working conditions is only in the neighbourhood of 20 volts. Each sub-station supplies a comparatively small area, and under normal conditions the low tension distributors are not interconnected, so that if any mishap were to occur at any one sub-station the portion of the field affected would be limited to a comparatively small area. Provision has been made, however, for coupling the low tension feeders of the adjacent sub-stations, so that in an emergency it would be possible to feed through.

The service lines are tapped off the overhead distributors and conveyed to pole line oil switches mounted on the distribution poles. From the oil switches the service lines are carried to groups of two or three wells. In case of fire on the field it is possible to disconnect any individual service, and make the line entirely dead. These

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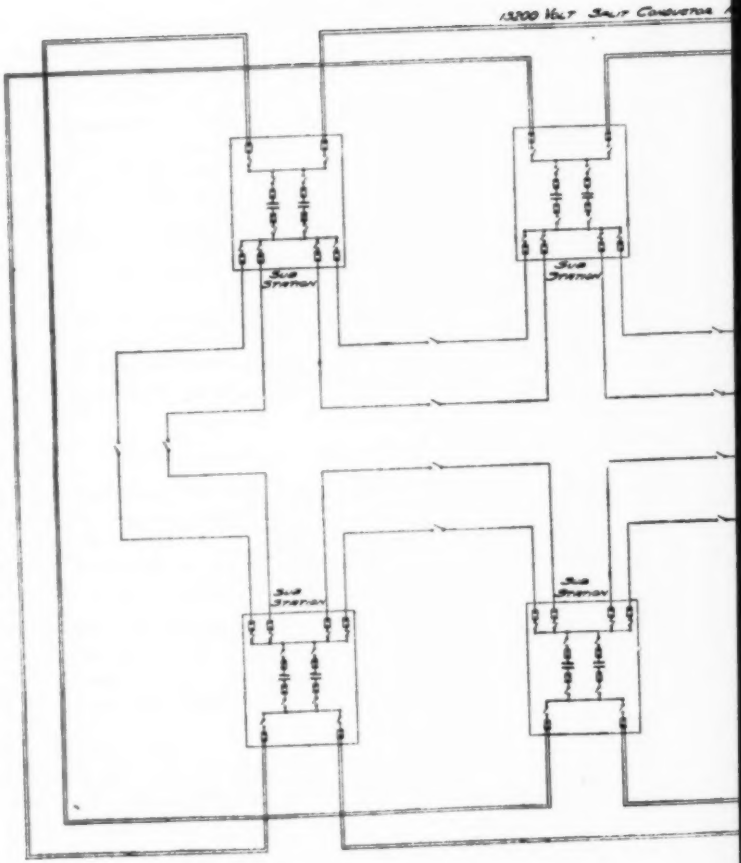
13200 Volt Split Conductor
Sub Station
Sub Station
Sub Station
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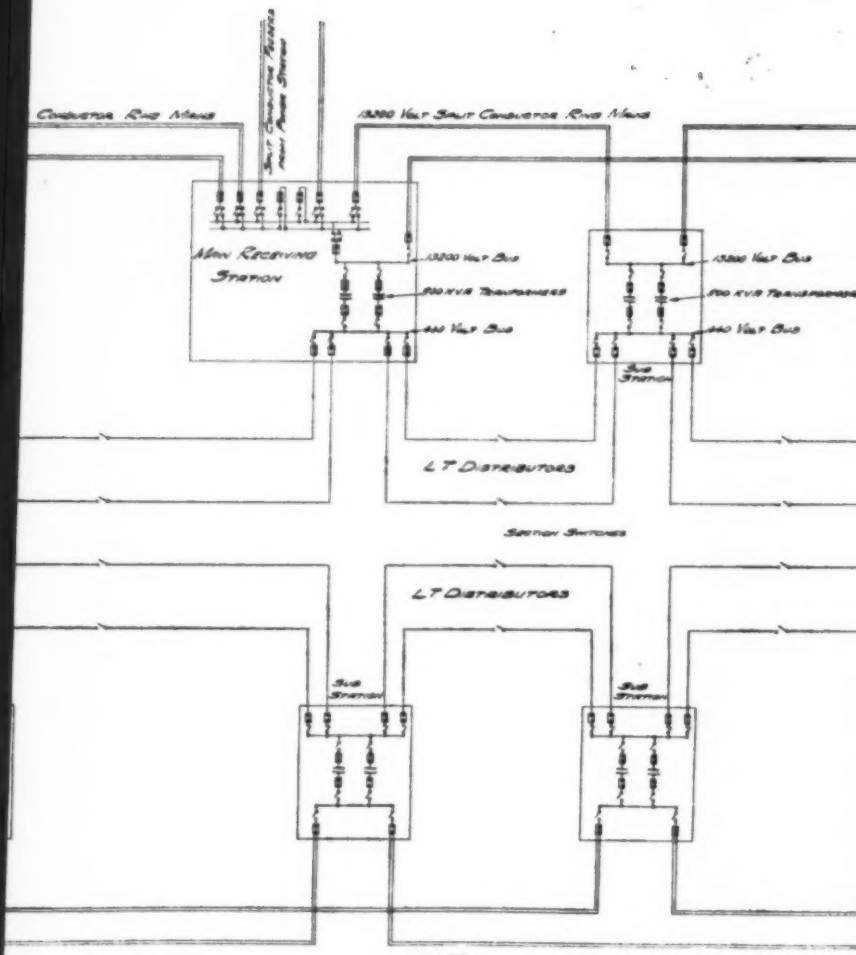
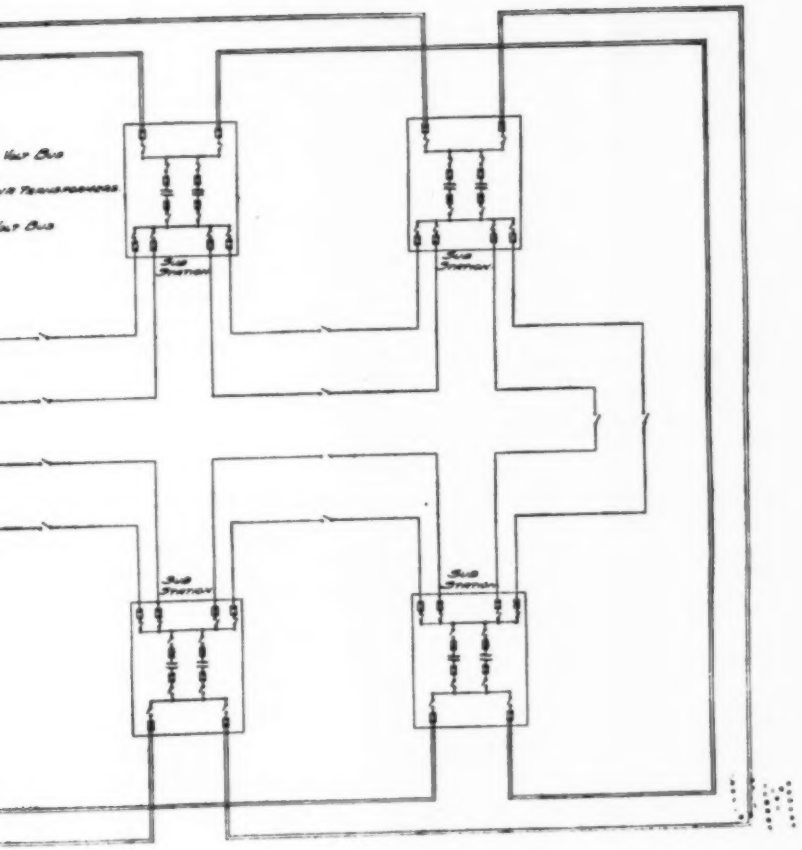


FIG. 18.

YENANGYOUNG OIL FIELD. DIAGRAMMATIC SCHEME OF H.T. AND L.T. DISTRIBUTION.



T.

service lines are carried on a similar design of Bates Pole, somewhat lighter than that employed for the main distribution feeders.

Oil Well Equipments.

The actual service connection to the Motor Equipments is made by means of an insulated cable carried on porcelain insulators, and brought into the motor-house through porcelain bushes. This service is taken to three ironclad fuses and thence through a three-phase unbalanced integrating watt-meter, and so to the terminals of the oil switch controlling the motor which operates the well.

The well equipments themselves are of two distinct types, *viz.*, for pumping and for drilling purposes. The pumping equipments consist of two-speed motors, rated 30/12 h.-p., running at a synchronous speed of 1000 or 500 r.p.m. The drilling equipments are single-speed machines, rated at 75 h.-p., running at 750 r.p.m.

Both pumping and drilling motors are designed and installed so as to reproduce, as closely as possible, the conditions which existed with the steam engine drive; thus, beyond the fact that a different type of prime mover is being used, there is practically no modification in the operation of the wells. This greatly facilitated the conversion and enabled the operators to become acquainted with the handling of the new plant with the minimum of difficulty.

Miscellaneous Application.

As already indicated, the economy which can be effected on an oil field such as Yenangyoung is not limited by the application of electricity to the wells alone. In the present instance electrical drive is also employed on auxiliary plant of a very varied nature. The more important installations of this character are:—

1. The main line oil-pumping station.
2. Water service to the fields, and for domestic purposes.
3. The oil collecting and pumping stations on the field.
4. The various workshops.
5. Rope-way.
6. Ice-making plant.
7. Lighting and fans for bungalows.
8. The actual illumination of the oil field area and individual rigs.

The economy which has resulted from the conversion of these plants is already very marked, and is a considerable factor in the operating economy of the whole system. It would prolong this paper unduly if a detailed description of each individual conversion

were attempted, but as a matter of general interest the author refers briefly to one or two more prominent features.

Main-Line Oil Pumping Station.

This station pumps the crude oil a distance of 300 miles to the refinery on the coast at Syriam. In this length of line three intermediary pumping stations are introduced. The original lay-out provided steam-operated high economy plunger pumps of Weir make, capable of delivering 12,000 gallons of crude oil per hour at a pressure of 550 lbs. per sq. in. Naturally this station entailed separate boiler plant and separate staff for operating it. Two of the steam pumps have been dismantled, and in their place have been substituted electrically-operated plunger pumps having a capacity of 13,000 gallons per hour at 550 lbs. pressure. These pumps are driven by three-phase, 440-volt, slip-ring motors having an output of 120 h.-p. when running at 415 r.p.m.

In order to render the system secure and avoid any possibility of igniting inflammable vapour which is liable to be present in a pumping station of this description, the motors are enclosed and supplied with air from an outside source by means of separately-driven fans. In the event of a possible breakdown in the motor occurring while inflammable vapour were present, this will effectually prevent any access of the explosive or inflammable mixture to the motor windings. The fan is interlocked with the main motor drive, so as to ensure its operation before the pump is started up.

All cable is three-core, lead-covered and armoured, and enters the motor and control apparatus through sealing boxes, similar to those provided for motor plant used in fiery mines.

Water Services.

The problem of an efficient supply of water to the fields, and for domestic purposes generally, has always been a difficult one on the Yenangyoung Field. Owing to the erratic behaviour of the river Irrawaddy, and the great variation in its head, which amounts to as much as 40 ft. between minimum and maximum levels, this was accomplished in the past by means of floating barges, which were a source of continual trouble. With the advent of the electrical scheme it was decided to install a permanent pumping station. The station in question has been built of reinforced concrete in the form of a rectangular caisson. The pumps are placed in this building at slightly below mean water level, so that for part of the year they are operating submerged, and for the remainder with a suction lift. High-speed motor-driven turbine pumps are provided,

running at 1470 r.p.m., and delivering against a head of 440 ft. from all causes. The same building also houses the low lift centrifugals which are employed for supplying water to the condensing plant.

Oil Collecting and Pumping.

A motor-operated plunger pump has been adopted for permanent pumping stations on the field, and is used both for crude oil and water pumping. The extension shaft, which this photograph shows very clearly, is to enable the provision of a barrier wall between the motor and the pump when used for crude oil. This arrangement was considered advisable as a precaution against any injury or breakdown in the motor causing a fire.

As mentioned above, there are various other applications of electrical power which all contribute to the general efficiency of the field, and the amenities available for the staff. An important feature is the lighting of all well rigs, so that night-work is considerably facilitated. There are many considerations of this nature which are liable to be overlooked when striking a balance between the advantages of different modes of working, but they are by no means unimportant, and all contribute to the success which follows operation by electricity.

An interesting contrast with the modernised system of oil-well operation, which the Burmah Oil Co. have introduced at Yenangyoung, is shown by the illustration of a native well on the same field.

It is worthy of note that the benefits of this very important project are not confined to the Burmah Oil Co. alone. Although the Burmah Oil Co. have provided all the capital, and are carrying the entire risk of exhaustion of the field, they have invited and secured the co-operation of the numerous other oil companies who operate on the same territory, as co-operative consumers, the Burmah Oil Co. undertaking to provide them with electrical energy at cost pro-rated between themselves and all other consumers. There is, therefore, no prospect of rival supply schemes on the same field, which, in view of the small area and congested condition, would not only have made the engineering work much more difficult, but might have been a fruitful source of friction between the various oil interests concerned.

Mention has been made earlier that this scheme was inaugurated in August, 1922. The time which has elapsed since then has been occupied in changing over from the old to the new system. In spite of this being a transition period, it is gratifying to note that the results secured to date lead one to anticipate all the advantages and economies which were originally hoped for. This particular

scheme is in a way a land-mark in the history of the crude oil industry, but there is still very wide scope for the employment of electrical energy in all the operations of oil field work, and no one contemplating reorganisation of any system or the development of fresh fields can afford in future to disregard the benefits which electrical operation offers.

In conclusion, the author wishes to express his indebtedness to the Burmah Oil Co., Ltd., for their courtesy in allowing him to reproduce drawings and photographs of their Yenangyoung Installation; also to the International General Electric Co., the Westinghouse Co. of America, and other makers, for permission to use illustrations of their plant and various data which he has received from them at different times.

The President said that the paper had been most interesting, and one full of valuable information, showing that much time and trouble had been spent on its preparation. It was pleasing to hear that the general complaint of non-flexibility had been overcome, and he trusted that any prejudice against such installations on this account would now rapidly disappear. He was much struck by the author's description of the Hild differential change speed system and its control gear. If an extended test proved satisfactory it might become an almost indispensable fitting for rotary drilling. In reference to the question of gas for raising steam, as there was a supply of gas in the field no doubt the arrangement was the very best that could be made. One advantage of the steam turbine plant was that less skill was required in running it than in other cases, and the up-keep was considerably less, so that the decision to use gas was very wise. Of course, should oil have to be used, it would not be so economical as if used in a Diesel engine.

DISCUSSION.

Mr. J. Gillespie said that as engineer to the Burmah Oil Company he had been closely associated with Mr. McCarthy-Jones in the design and development of the Electrification Scheme, which formed to a large extent the subject of the paper which had just been read.

In view of his association with the author, he did not think it would be in order for him to make any comment on the paper. He could not add to its lucidity; and he had no intention of attempting to amplify it. As a Member of the Institution he desired to thank the author for a very interesting and important addition to the Transactions, and as an individual he must offer his own personal thanks in one direction. During these five years the speaker had been so much involved in the details of the scheme

that it was sometimes difficult to regard it as a whole and from the outside. He was rather in the position of one who could not see the wood for the trees.

That night he felt that the author had raised him from the undergrowth and made it possible for him to regard the subject as a whole, and it was now more attractive than it had appeared during the time when they were engaged upon it. He hoped the discussion which would follow would be as full and general as the subject and the paper deserved. There was only one practical point he would like to mention, in the hope that he might elicit some information from any who were present. The present author had referred, as had also Mr. McCollum* in the paper he read before the Institution a short time ago on Rotary Drilling, to the capacity of the motor necessary for rotary drilling. Both these gentlemen had spoken of 75-h.p. motors, and that was the capacity of the motors which had been provided for rotary drilling in Burma so far. They had recently been asked, however, to increase the h.p. to 100. It should be understood that these ratings were not required for the actual work of drilling, but rather for the handling of the heavy strings of casing involved in deep drilling. If anyone present was able to give him assistance in this matter he would be very much indebted.

Mr. Leon Gaster said that in 1902, when he visited Rumania he saw one of the first applications of electricity for drilling and pumping purposes and reported favourably on the scheme adopted. The current was generated at 3,000 volts, transmitted at 11,000 volts, and retransformed to 500 volts for the three-phase motors. That particular installation was interesting because water power was utilised in generating the energy required, which was also applied for lighting the town and the King's Summer Palace at Sinaia. The fluctuating condition of the water supply, however, due to drought in summer or freezing in the winter, put the owners of the oilfields in the dilemma of not having a reliable source of energy; but the promoters of the scheme of power transmission found a solution of the problem by adopting, in addition to steamplant, the use of Diesel engines as a stand-by. Diesel engines were installed in 1901, and at the time were believed to be the largest size manufactured, namely 100 h.p. each, and the consumption of oil was only 0.25 litre per h.p.

In the early days in Rumania trouble was experienced from lightning, owing to the absence of satisfactory lightning arresters. He wondered whether the author met with similar troubles in the Burma installation.

* *Jour. Inst. Petr. Techn.* x., No. 41, p. 1, 1924.

Mr. Roland V. Wallis, on the question as to the power being used on any other field, said that motors for drilling with rotary had already been delivered to Baku, Russia. A 75-h.p. motor had been ordered for the rotary machine, that is, the same as in Burma. It should now be already running, and probably within a month they would hear how it was working.

The first well on the Baku oilfields to be drilled by electricity was so drilled in 1893; it was run from a private station. Eight years later—in 1901—the public electric station was functioning.

Mr. Campbell M. Hunter said that he would be glad if the author could furnish any information on the use of single-phase motors for oilfield purposes.

In 1907 he was consulted on the question of installing electric power on a property in Northern Peru. Although up to that time Baku was the only field on which electric power for bailing and drilling had been extensively used, the Allgemeine Electricitäts Gesellschaft put forward a very interesting proposal embodying the use of single-phase motors. The claims made for wide speed variation and general flexibility led him to visit Berlin to discuss the problem with that company's chief electrical designer. The motor recommended for the purpose certainly possessed very remarkable properties, which, however, could of course only be tested out on an oilfield. Unfortunately, it was decided not to proceed further with the question of installing electric power, so the matter dropped, and, to the best of his information, no tests have ever been made with single-phase motors on any oilfield.

Mr. F. G. Rappoport said that a few months ago he had the opportunity of going over the installation described, and of seeing some of the plant at work in the field. It was certainly the latest and most up-to-date oilfield electric power installation, and, one might safely say, the last word on the matter. Before the arrangement was come to by which all the large firms in the Yenangyoung field combined for the purpose of participation in this method of power supply, the speaker had himself examined the subject on the much smaller scale, when it was only a question of one concern building a power plant for its own purposes. A clear direct saving of considerable amount was indicated, but the large indirect saving lay in the 150,000 barrels or so of crude oil, then being used under the wasteful steam method, being made available under the new power scheme, for commercial use and profit making. The estimated cost of the unit amounted to $1\frac{1}{2}$ annas, or $1\frac{1}{2}$d. This has been bettered as has been shown by the author of the paper, the actual cost per unit amounting to 1d. This is doubtless due to the larger system eventually installed, as it is, of course, axiomatic

in electric power working that the larger the system the more cheaply can the unit be supplied and the more efficiently the plant be worked.

The case is similar in the Russian oilfields. Some years ago, in a paper* dealing with the internal-combustion engine, the writer worked out some comparisons from actual practice in that field between the old steam plant and electric power. The costs were halved on the average, the advantage increasing in favour of electric power with higher costs of fuel. These figures took into account depreciation and interest on capital. The use of electric power for oilfield work dates so far back as the year 1900 or 1901 in the Russian oilfields, which may thus almost be regarded as the pioneers of this form of power.

The use of electric power in the Baku oilfields has progressively increased. It was 20 million kilowatt hours in 1906, and had increased to 150 million kilowatt hours in 1914. Since then it has increased to 210 million kilowatt hours last year. In fact, to-day 69 per cent. of all the wells in the Baku field are being electrically worked, and of the producing wells no less than 81 per cent.

One sees the same in Galicia, where the use of electric power is beginning. The speaker had occasion some two years ago to visit the Premier Company's installation at Boryslaw while it was still under construction. It has, he believed, since been completed, but he had no figures of the actual running of this plant. The plant is a comparatively small one, as the idea of electrifying the whole field, with the consequent economies, has not yet been developed. The size of the station is 2600 h.p. Natural gas was to be used fired under 3 Garbe type of water tube boilers of 280 sq. metres heating surface, working at 150 lbs. pressure, and with 300 deg. of superheat. The rate of consumption of gas was reckoned at 0.8 cubic meter per h.p. per hour. The prime movers are two Curtis steam turbines of 2600 h.p. driving alternate current generators running at 3000 revs. and 50 periods. The method of distributing the power is of interest. This is distributed into three separate districts or circles surrounding the power station, each at the most economical pressure of transmission. Thus, the current passes into the first, or nearest, circle at 3000 volts, which is the voltage of generation; into the second circle at 15,000 volts by transforming; and into the third, or farthest circle, at 50,000 volts. In each of the last two cases the voltage is transformed down to 3000 volts at the point of use. The steam consumption was guaranteed 5 kg. per h.p. hour. The production motors were 275 kilowatts power with an overload capacity of 100 per cent. This high power is necessary in the Galician fields, as production

* *Journ. Inst. Petr. Techn.* I, 4, 195. June, 1915.

takes place largely by baling and swabbing, processes which, as is known, consume much power. The drilling motors are rated at 44 kilowatts, again with an overload capacity of 100 per cent. It was reckoned at that time that a monthly saving of £5500 would result, and that in the saving of fuel alone the whole plant could be amortised in three years.

These facts show the extent to which electric power is being developed in these older oil fields. Its use in America is well known.

Its disadvantage lies in the fact that it can only be applied efficiently on a large scale, and therefore usually only to fields in a mature, or even declining stage. It is, in fact, when these stages have been reached in the life of an oilfield that production costs and fuel conservation begin to be more seriously considered. Unfortunately, there is often then much hesitation about scrapping existing plant, however old and inefficient, except by those who take the long view. In this respect, the bold action taken at Yenangyoung is one to be emulated when the occasion arises in other fields.

The Institution was concerned in noting the progress of all new developments, and this paper certainly marked an advance in a very important branch of the engineering side of oilfield work.

Mr. W. S. Fellows, on the question raised by Mr. Gillespie with regard to the power of the motors, said that some two or three years ago, on the California fields, motors of 100 h.p. were tried out, and it was found that for various reasons—among others, that which the author spoke of, namely, the inefficiency or the difficulty of the control—these were unsuitable in certain operations. More particularly for the rock bits, which had to be rotated at a very slow speed, motors of 100 h.p. were found difficult of control. The manufacture of these drilling motors then decided that for general purposes of drilling the 75-h.p. motor was more suitable. As far as the statement of Mr. Wallis was concerned, regarding the electrical equipments sent out to Russia, these had not up to the present been put into actual use, but the speaker thought there was no doubt that they would prove just as useful in Russia as the same type of equipment had proved on the Californian fields and the Burma fields.

Mr. Gordon Pitt felt that he must utter a mild protest when the author said, towards the end of his paper: "There is still very wide scope for the employment of electrical energy in all the operations of oilfield work"—up to that point he was not at all inclined to join issue with him—"and no one contemplating re-organisation of any system or the development of fresh fields can afford in future to disregard the benefits which electrical operation

offers." He did not want to suggest that the benefits which electrical operation offered could be disregarded, but it was surely not the case that in fresh fields the outstanding advantages of electrical installation were so well marked as in the cases which the author had described. Where they had, as in Burma, a comparatively limited area and congested work, probably general electrification for all the work was the ideal, but where the conditions were very different, the work very isolated, the wells distributed over large areas of country, all remaining under the same control and operated by the same staff, and where the work from an early stage was likely to develop, to bind oneself from the beginning to electrical methods of installation was a plan which, at all events, required very careful consideration. This was especially the case where transmission was through jungle country, such as the speaker had had a great deal to do with. When it was a question of developing new wells he thought a stage had to be reached by the older methods before electrical methods could be put into operation. In the early stages the laying down of very expensive electrical equipment for some thousands of h.p. might not be wise, and it might be well to wait until the general development of the field had indicated that that concentrated and centralised method of obtaining energy was going to be the most economical.

Mr. McCarthy-Jones, in reply, thanked the members for the kind reception they had given to his paper.

The Chairman had referred to the fact that steam turbines were employed in Burma. In this connection the question of the best type of prime mover employed was one which was very carefully considered. If Diesel engine plant had been installed, the Burma Oil Company would not have been able to utilise the natural gas available at the present time. Moreover, the scheme would have entailed larger individual Diesel units than had been adopted in general practice operating in a very remote part of the world. Gas engine plant would have suffered from the same disability in regard to the size of the generating units and would also have committed the company to a type of prime mover which would have been valueless had the supply of natural gas become exhausted. In these circumstances it was felt the best policy was to employ steam turbine plant, particularly as the size of the units enabled one to secure a very satisfactory overall thermal efficiency.

The question which Mr. Gillespie raised regarding the horse-power of drilling motors is one regarding which it was not wise to be too dogmatic. The general consensus of opinion, gathered from the practice on American fields, was that the 75-h.p. machine is the most useful size to adopt. There were undoubtedly conditions, however, where very deep holes were encountered and at the same

time the formation was of a caving nature, where it might be desirable to use more powerful machines in order to handle the long lengths of heavy casing which were now becoming more general. Of course, when handling these big weights very much depended on how many ropes were employed in the line. Provided there were facilities on crown block for the requisite number of lines to handle the casing, he was of the opinion that it was advisable to limit the capacity of the drilling motor to 75-h.p. when possible.

The author was interested to hear what Mr. Leon Gaster had to say with regard to Rumania. Of course, he was aware that in Rumania and Russia electrical operation was adopted much earlier than in many of the other fields. America had been backward in that respect : one might say it was only during the last ten years that America had really began to realise the advantages of utilising this form of power for oilfield work.

With regard to lightning arresters, the Burmah Oil Company had been practically immune from lightning trouble. It was probable that, in the days Mr. Gaster referred to, the science of lightning arresters was not so well-known. In Burma they had used the oxide film arrester throughout, and though the electrical storms there were not unusually violent, the author had witnessed several which could be described as severe.

With regard to the question asked by Mr. Campbell Hunter as to the employment of single-phase motors, the author had had no experience of the adoption of this type of machine for oil well operation and was not particularly desirous of ever having it. The single-phase motor seemed to him essentially the wrong type of machine to put down for work of that description. The proposals which were put forward to Mr. Hunter in 1907 presumably included a commutator type of machine, as otherwise the very wide speed regulation required would hardly have been feasible. Apart from the fact that this design would introduce a commutator and commutator brushes, a feature which is not desirable for oilfield work, the very wide range of torque necessary would not be available in a motor of this design. The author had never heard of a single-phase proposition for the operation of an oilfield before and knew of no case where single-phase machines were in actual use for pumping or drilling work.

The figures which Mr. Rappoport had given regarding the use of electricity on the Russian fields demonstrated very clearly that the advantages of electrification were appreciated in that district. The most obvious economy in the case of a field such as Yenangyoung was, as Mr. Rappoport stated, in the immense saving in crude oil. In other words, electrical operation conserved the oil supplies, and, as the author had mentioned in his paper, this was one feature which tended very materially to prolong the life of the

field. He wished, however, to clear up the misunderstanding regarding the actual cost per unit. The curve shown, although based on the results secured in Burma, was not intended to represent actual costs on that field. Apart from the capital charges, the main item in the cost per unit for a plant of this description is the cost of fuel, and the curve which the author had shown was merely put forward to justify his comparison of steam drilling at 1d. per unit and the price of oil fixed at 10s. per barrel. A very much lower operating cost than 1d. per unit could be shown if, for instance, the fuel employed were natural gas and the value attributed to this gas were less than the equivalent of the figure of 10s. per barrel of oil mentioned by the author to illustrate his argument.

The author was very interested in the particulars which Mr. Rappoport supplied of the Premier Company's installation at Boryslaw. It was interesting to note in this connection that an estimated consumption of gas of 0.8 cub. metres per h.p.-hour had been very considerably bettered in the Yenangyoung installation.

The author is not of Mr. Rappoport's opinion that electricity can only be applied efficiently on a large scale. There are numerous cases of small installations where the economy effected by installing electrical drive has made all the difference between commercial success and failure.

With regard to Mr. Gordon Pitt's criticism of the last paragraph of the paper, the author agreed that his statement was apt to be misunderstood in so far as it did not apply to exploiting new fields or "wild-catting." He did not intend to argue that electricity should be necessarily adopted in the very early stages, but once the sands had been proved it would best serve the interests of economy to go right ahead with an electrical scheme. There is such a very wide margin between the economy effected by electrical operation and the ordinary method of steam operation that even if the electrical installation is only started in a small way it will very rapidly repay for any slight additional capital charges at the outset.

ANNUAL REPORT OF THE COUNCIL FOR 1923.

THE Council, in presenting their Annual Report, together with the Accounts to December 31st, 1923, have much gratification in stating that the Institution has made considerable progress during the period under review.

The following statement shows the membership of the Institution at December 31st, 1923 :—

Honorary Members	9
Members	340
Associate Members	165
Students	110
Associates	32
Total	656

being an increase of 94 over the preceding year, and at that date 11 were awaiting election.

During the year the amount received from the sale of Journals was £295 3s. 10d., as compared with £351 16s. 8d. for 1922.

The revenue derived from the Advertisements continues to increase, and the circulation of the Journal is now about 1,000 copies per issue.

ACCOUNTS.

The Council are pleased to state that the attached Balance Sheet shows an entirely satisfactory Financial position. The expenses of publishing the results of the Standardization Committee's work have still to be met.

The results of the work of the Standardization Committee are about to be published in book form, the copy for which is now in the printer's hands. The Council are greatly indebted to the Members of the Committee for the valuable work that they have done, and feel quite sure that the book will prove of exceptional interest and utility.

The Institution is represented on :—

The British Engineering Standards Association, The Imperial Mineral Resources Bureau, The Fuel Economy Committee, British Association for the Advancement of Science, The Committee of Birmingham University, which is

responsible for the Education of Petroleum Technologists, The British Empire Exhibition (1924) (Chemical Section), The Empire Mining and Metallurgical Congress to be held at the British Empire Exhibition, The American Society for Testing Materials.

Official representatives attended the International Petroleum Exposition and Congress, held at Tulsa, Oklahoma, U.S.A., in October, 1923.

During the year the following papers were read :—

At the Sixty-eighth General Meeting : "FURTHER INVESTIGATIONS INTO THE PHYSICO-CHEMICAL SIGNIFICANCE OF FLASH-POINT TEMPERATURES," by W. R. Ormandy and E. C. Craven.

At the Sixty-ninth General Meeting : "SOME PRACTICAL NOTES ON OIL PUMPING," by G. W. E. Gibson.

At the Tenth Annual General Meeting : "FIRE HAZARDS AND FIRE EXTINCTION," by J. S. S. Brame (Presidential Address).

At the Seventieth General Meeting : "POTRERO No. 4 : A HISTORY OF ONE OF MEXICO'S EARLIEST AND LARGEST WELLS," by A. E. Chambers.

At the Seventy-first General Meeting : "HEAVY GRADE EGYPTIAN CRUDE PETROLEUM," by W. A. Guthrie.

At the Seventy-second General Meeting : "RECENT RESEARCHES BEARING UPON THE ORIGIN OF PETROLEUM," by E. H. Cunningham-Craig.

At the Seventy-third General Meeting : "GALICIAN-CANADIAN POLE TOOL FISHING METHODS," by Albert Millar.

At the Seventy-fourth General Meeting : "THE MODERN ROTARY DRILLING SYSTEM," by L. R. McCollum.

The average attendance at the meetings was 73 Members and 37 visitors, making a total of 110.

In addition to the above, the following papers were published in the Journals :—

In Journal No. 36 : "A METHOD FOR EXPRESSING THE VALUE OF MIXING AGENTS BETWEEN HYDROCARBONS AND 95 PER CENT. VOL. ALCOHOL," by W. R. Ormandy and E. C. Craven.

"FREE SULPHUR IN MOTOR FUELS, ETC.," by W. R. Ormandy and E. C. Craven.

In Journal No. 37: "THE AMOUNT OF UNDEVELOPED OIL LAND IN THE BAKU DISTRICT," by D. V. Golubiatnikoff.

In Journal No. 38: "AVIATION SPIRIT—PAST, PRESENT AND FUTURE," by A. E. Dunstan and F. B. Thole.

"THE NATURE OF LUBRICATION IN ENGINEERING PRACTICE," by T. E. Stanton.

"OIL CONFERENCE AT SIXTH INTERNATIONAL MINING EXHIBITION: THE RIDDLE OF THE CARPATHIANS," by E. H. Cunningham-Craig.

"OIL DEPOSITS AND TECTONICS OF VERTICAL PRESSURE," by M. Kraus.

"NOTE ON GENESIS OF HYDROCARBONS AND THEIR LOCALIZATION IN CERTAIN ZONES OF THE EARTH'S CRUST," by R. d'Andrimont.

"THE MODE OF APPEARANCE OF THE PETROLEUM DEPOSITS IN THE CARPATHIAN REGIONS, WITH GENERAL CONSIDERATIONS OF THE GENESIS OF THE PETROLEUM AND THE SALT OF THE ACTUAL DEPOSITS," by I. P. Voitesti.

"OILFIELD WASTE," by A. Beeby Thompson.

"AN ECONOMIC STUDY OF PETROLEUM MINING BY UNDERGROUND DRAINAGE," by J. A. Lautier.

In Journal No. 39: "EQUILIBRIUM BOILING-POINT AND LATENT HEAT OF VAPORISATION OF MOTOR FUELS," by W. R. Ormandy and E. C. Craven.

"SOME PHYSICAL PROPERTIES OF LUBRICANTS," by Elliot A. Evans.

"ASPHALT IN LUBRICATING OILS," by Elliot A. Evans.

"PSYCHO-GALVANIC MEASUREMENT OF SMELL," by S. J. M. Auld.

In Journal No. 40: "CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF CASE SCHOOL OF APPLIED SCIENCE, ON THE LUBRICANT AND ASPHALTIC HYDROCARBONS IN PETROLEUM," by Charles F. Mabery.

"A STUDY OF VISCOSITIES OF FUEL OIL MADE FROM PANUCO CRUDE," by R. H. Brownlee and W. H. Coburn.

"FUEL RESOURCES AND SUPPLIES FOR ROAD TRANSPORT," by Sir Edmund J. W. Slade.

"THE INTERNATIONAL PETROLEUM EXPOSITION AND CONGRESS," by F. B. Plummer.

Mr. Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., has been uanimously re-elected President for the ensuing year.

The Rt. Hon. Viscount Cowdray of Cowdray, Sir George Beilby, Sir John Cargill, Sir Thomas Holland, Mr. Alfred C. Adams, and Mr. Arthur W. Eastlake have been unanimously re-elected as Vice-Presidents for the ensuing year.

Mr. Robert Redwood has been unanimously elected as a Vice President for the ensuing year.

During the year the Council decided to form a Students' Section of the Institution, and several meetings of Students were held and two Branches of the Section—namely, London and Birmingham—formed, and Meetings, at which papers have been read, have been held by the Branches.

The Institution is indebted to Messrs. The Anglo-American Oil Company, Limited, for their generosity in presenting the sum of £100 to be expended in providing prizes and scholarships for Student Members.

The Institution was represented at the Sixth International Mining Exhibition, at the Agricultural Hall, and a reception was held and attended by a large number of members and visitors. In addition a House Warming of the new offices taken by the Institution at Aldine House, and an Exhibition of Scientific Apparatus, took place on October 3rd, at which nearly 200 were present, including many ladies.

The attendance at the Fifth Annual Dinner, the arrangements for which were in the hands of Messrs. Ashley Carter and William Sutton, assisted by Mr. George Sell, was over 200 and the dinner was a great success.

The Council have great regret in announcing the deaths of Mr. P. C. A. Stewart, Mr. W. L. Samson and Mr. W. H. W. Willcox.

The Council wish to express their thanks and appreciation of the courtesy extended to the Institution by the Royal Society of Arts for their kindness in allowing the use of their House for Meetings, and to the Chemical Industry Club for permitting the use of their premises to the Members of the Institution's Dinner Club.

The Council gratefully express their appreciation of the services rendered by Sir William Plender, Bart., G.B.E., Honorary Treasurer,

Messrs. Ashurst, Morris, Crisp and Company, Honorary Solicitors, Messrs. Price, Waterhouse and Company, Honorary Auditors, Dr. A. E. Dunstan, Honorary Editor, and also to the Secretary and his staff.

The Honorary Auditors retire, and being eligible have kindly consented to agree to their re-election.

By order of the Council,

ARTHUR W. EASTLAKE,
Honorary Secretary.

REVENUE ACCOUNT for the Year ended 31st December, 1923.

DR.

	£	s.	d.
To SALARIES	619	19	4
„ RENT, RATES, ETC.	332	8	11
„ PRINTING AND STATIONERY	906	7	6
„ POSTAGE	66	1	7
„ HIRE OF HALL FOR MEETINGS AND EXPENSES OF MEETINGS	226	10	8
„ ABSTRACTS AND REVIEWS	212	18	2
„ EXPENSES OF STANDARDIZATION COMMITTEE	146	16	5
„ STUDENTS' SECTION EXPENSES	25	9	10
„ SUNDRY EXPENSES	325	16	0
„ DEPRECIATION OF LIBRARY AND OFFICE FURNITURE ..	26	11	5
„ BALANCE CARRIED TO BALANCE SHEET	173	14	2
	£3062	14	0

CR.

	£	s.	d.	£	s.	d.
By SUBSCRIPTIONS :—						
Members	1490	18	6			
Special	1020	0	0			
				2510	18	6
„ INTEREST AND DIVIDENDS				97	4	2
„ SALE OF JOURNAL				237	17	6
„ ADVERTISEMENTS IN JOURNAL				175	9	2
„ SALE OF BOOK "THE PETROLEUM INDUSTRY"				41	4	8
				£3062	14	0

BALANCE SHEET as at 31st December, 1923.

LIABILITIES.

	£ s. d.	£ s. d.	£ s. d.
To CAPITAL OF THE INSTITUTION, under Bye-Law Section 6, par, 14, viz.: Life Membership Fund, as per last Account		413 0 0	
Entrance Fees, per last Account ..	704 10 0		
Additions during year	132 6 0		
		836 16 0	
Donations, per last Account ..		300 0 0	
			1549 16 0
„ STUDENTS SPECIAL PRIZE AND SCHOLARSHIP FUND			100 0 0
„ SUNDRY CREDITORS			192 4 7
„ SUBSCRIPTIONS PAID IN ADVANCE ..			249 7 6
„ ENTRANCE FEES PAID IN ADVANCE (pending election)			1 1 0
„ REVENUE ACCOUNT— Balance, 31st December, 1922 ..		1587 4 0	
Less: Arrears of 1922 Subscriptions written off	16 5 6		
Less: Arrears of Subscriptions recovered	11 5 6	5 0 0	
		1582 4 0	
BALANCE FOR YEAR, AS PER REVENUE ACCOUNT		173 14 2	
			1755 18 2
			£3848 7 3

ASSETS.

	£ s. d.	£ s. d.
By INVESTMENTS, AT COST—		
£664 6 6 London County 3% Consolidated Stock	481 10 6	
£825 0 0 War Loan, 5% 1929–47	761 3 7	
£50 0 0 War Bonds, 5% 1927	50 0 0	
£150 0 0 Birmingham Corporation 6% Stock	146 16 0	
		1439 10 1
Note.—Market price of above Investments on 31/12/23=£1466.		
„ OFFICE AND LIBRARY FURNITURE (excluding presentations)—		
As per last Account	348 1 1	
Additions during Year	213 7 1	
	561 8 2	
Less: Sales during year £30 0 0		
Depreciation at 5% .. 26 11 5		
	56 11 5	
		504 16 9

	£ s. d.	£ s. d.
By Library (Books) (excluding presentations)—		
As per last Account	110 18 0	
Additions during year	14 4 0	
		125 2 0
„ Subscriptions (1923) outstanding at date and considered collectible		52 10 0
„ Sundry Debtors		91 4 0
„ Cash on Deposit		1123 8 2
„ Cash at Bank and in hand		511 16 3
		£3848 7 3

H. BARRINGER
A. DUCKHAM } *Members of Council.*

We have examined the above Balance Sheet with the Books of the Institution, and having obtained all the information and explanations we have required, we are of the opinion that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institutions affairs, according to the best of our information and the explanations given to us and as shown by the Books of the Institution.

3, Frederick's Place,

PRICE, WATERHOUSE & CO.

2nd February, 1924.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

The Eleventh Annual General Meeting of the Members of the Institution was held at the house of the Royal Society of Arts, on Tuesday, March 11th, 1924, Mr. H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A.,President, occupying the Chair.

The Secretary read the Notice convening the Meeting, and the Minutes of the Tenth Annual General Meeting, March 13th, 1923, which were signed as correct.

The President announced that the list of members elected and transferred during 1923 was on the table for inspection.

The President, in moving the adoption of the Annual Report for 1923, remarked that all the members had a copy of the Report before them, which set out very shortly the work of the Institution, giving a list of the papers which had been read, and a general idea of what had been done during the past year. There were, however, one or two points which might be a little elaborated. The Standardization Committee had now completed its labours and the thanks, not only of the Institution, but of the Industry were due to the gentlemen who composed that Committee, and the co-opted members, who had expended such a great deal of time and labour on the work. The Report of that Committee was now ready for publication and it would be found a most valuable document. The Committee had had an enormous amount of correspondence, and if the members would notice in the *Journal* the list of the co-opted members they would realise what an amount of investigation the matter had required.

The next point to which he wished to refer was that Students' Branches had been established in London and in Birmingham. Very satisfactory reports had been received from those branches, which would be read at a later period of the meeting. Both branches seemed to be in a very flourishing condition. There were now 115 Student members in the Institution, the total membership amounting to 670.

He would also mention that the Institution had now moved into its new premises, the conveniences of which were much appreciated by the members, and where the Students, who held their meetings in the large room, could be accommodated, a screen and lantern having been installed for their use. The Secretary and staff had had a great deal of extra work thrown upon them by reason of the

removal, but it had been accomplished and everything placed in order in record time. (Applause.)

The Secretary read the Annual Reports of the two Students' Branches as follows :—

LONDON BRANCH.—In May, 1923, two meetings of the Student Members were held to discuss the formation of a Students' Section. Mr. H. Barringer, President of the Institution, presided at the first of these and outlined to the Students present the proposals of the Council, which were, in effect, that the Section should be organised and conducted by the Students themselves, the Council to exercise nominal control only. An Honorary Secretary was appointed, and arrangements made to hold a further meeting to appoint a Committee. At the second meeting the following Students were appointed to form the Committee: Messrs. H. G. Austin, F. E. J. Foxall-Smedley, H. S. Garlick, C. O. Graham, F. R. S. Henson, A. B. Miskin, R. F. Owen, and M. Stern.

During the summer months a set of rules was drafted and arrangements made for the forthcoming winter session, and the rules received the approval of Council.

It is interesting to note that at the time of the formation of the Students' Section there were approximately 70 Student Members of the Institution, while at present there are over 110 Students, and several applications have recently been received.

Meetings have been held monthly since October last and the following papers read :—

First General Meeting, October. "The Use of the Hand Auger in Geological Mapping," by F. R. S. Henson.

Second General Meeting, November. "Swabbing," by Albert Millar, A.M.I.Mech.E., Member.

Third General Meeting, December. "Some Properties of Cracked Gasoline," by A. B. Miskin.

Fourth General Meeting, January. "A History of the Oilfields of Mexico," by C. A. Sansom.

The first Annual General Meeting of the London Branch of the Students' Section was held at the offices of the Institution on Tuesday, February 19th, 1924.

The interest in the Section has been well sustained during the past year, and there is every indication that the membership will increase.

(Signed) H. G. AUSTIN,
Chairman and Hon. Secretary,
March 7th, 1924.

(Countersigned) H. BARRINGER.

BIRMINGHAM BRANCH.—The Inaugural Meeting of this Branch was held on October 30th, 1923.

At the first meeting, when there was a good attendance of both Student Members and guests, a Committee and Honorary Secretary were elected, and the Branch was fortunate in having a visit from Mr. Albert Millar, A.M.I.Mech.E. (Member) who read a paper on "Swabbing."

The next meeting was held on November 27th, 1923, when a very interesting and instructive paper entitled, "The Hydrogenation and Cracking of Mineral Oils," was read by Mr. H. G. Shatwell, M.Sc., Research Worker in the Mining Department of the Birmingham University.

A programme for the Session was also drawn up at the last Committee Meeting and a copy sent to each Member of this Branch.

Mr. Carl White's paper on "The Importance of Standardization for the Economical Development of Foreign Oilfields," which was to have been read on February 12th, has had to be postponed owing to Mr. White leaving for Russia, and Mr. Blakiston kindly consented to read his paper on "The Oilfields of Rumania" in place thereof.

(Signed) ALFRED W. NASH,
Hon. Secretary.
(Countersigned) H. BARRINGER.

Mr. A. Beeby Thompson, in seconding the motion, said everyone connected with the Institution must feel very gratified at the results shown in the Report. From a mere handful of people associated with the industry the Institution had steadily grown until at the present time it had a membership of over 600. It seemed inconceivable that twenty-five years ago the number of British technologists engaged in the mining side of the industry could almost be counted on the fingers of one's two hands. To-day there were thousands of qualified British subjects occupied exclusively with the technical side of the industry. One of the most important sections of the Institution was the education of Students. He had himself been able to tender some advice on the subject of all courses when they were first considered. It was at a time when those concerned with the industry were feeling the urgent necessity of trained technical aid on the fields; but he thought no one could possibly have foreseen the enormous developments which had taken place in the industry in the interval. Anyone associated with oilfields and refining must realise the great value, and the urgent need, of scientific aid. After all, extremely little was known about oil at present, and every day further and deeper research into all branches of the subject was needed. The

Institution had been very fortunate in having had some very first class Presidents. In Mr. Barringer they had a president who was a distinguished engineer with specialised knowledge of the engineering side of the industry. Mr. Barringer must have witnessed the growth of the oil tanker almost since the first one was made. If the Institution could only proceed on the lines it had been doing, and continue to get papers of the high standard which were now being contributed, it was bound to succeed. He was not one of those who believed that the exhaustion of natural oil was in sight. The industry was only in its infancy, and for many years to come the production of crude oil was more likely to increase than diminish.

No further discussion taking place the motion for the adoption of the Report was then put to the Meeting and carried unanimously.

The Secretary read the Auditors' Certificate with regard to the Balance Sheet.

The President moved the adoption of the Balance Sheet, and asked the Chairman of the Finance Committee, Mr. A. C. Adams, to explain the financial situation and to second the motion.

Mr. Adams, in seconding the motion, said he proposed to offer what explanations he could of the accounts which were before the members. The first item, the capital of the Institution, represented in fact the amount which the Institution had for investment purposes. It comprised the Life Membership Fees, Entrance Fees and Donations, all of which, under the By-Laws of the Institution, had to be invested. The interest on the invested funds was utilised for the purposes of the expenses and expenditure of the Institution. It would be noticed that at the end of last year there had been an amount of about £110 still remaining to be invested. That had been invested at the beginning of the present year. The item of Students Special Prize and Scholarship Fund was a new item, and, as the members had learned from the Report, was due to the generosity of the Anglo-American Oil Company. The Council had lately decided upon the terms on which the Scholarships and Prizes should be competed for the Student Members. The item of Sundry Creditors, £192 4s. 7d., comprised the usual outstanding bills to be paid at the end of the year, and which had since been cleared away.

On the other side of the Balance Sheet, he had dealt with investments. With regard to the item of Office and Library Furniture, there was an item there, "Sales during the year." That referred to the tenants fittings, and things which were left behind at John Street when the Institution moved, and which were taken over by the incoming tenants. Turning to the Revenue account, the

principal item which struck him as being larger than usual was that of Sundry Expenses. It included the expenses of moving into and decorating the new offices, and various larger items than usual which had had to be borne during the last year. It would probably be noticed that the sale of the Journal was not quite so much as it had been in 1922. That was due more particularly to a larger number of Journals being sold through Agents and, therefore, the Institution not getting quite so much for them; also that a large number of Journals now went to those who had become members, and therefore were not paid for as they used to be. With regard to investments, they were increased by £100 beyond the amount shown in the 1922 Balance Sheet. That represented the amounts which were due for investment last year and were so invested.

The result of it all showed that there was to the credit of Revenue Account a total of £1,755 18s. 2d. He was sure the members would agree that the finances of the Institution were on quite a sound basis.

The President said he was sure the members were much obliged to Mr. Adams for his remarks, and the thanks of the Institution were due to him. It was largely owing to Mr. Adams's skilful guidance that the Institution was in such a sound position as it was. (Applause.)

He enquired if any member desired to make any remark on the Balance Sheet.

A Member asked whether the Report of the Standardization Committee would be printed in the Journal, or sold separately.

The President said it would be sold separately.

The Member asked what the price would be.

The President said that the price had been fixed at about 6s. It was quite a large pamphlet of over 100 pages.

The motion for the adoption of the Balance Sheet was then put to the Meeting and carried.

The President said that up to the present time the auditors had done their work without remuneration, but they now asked for a fee of Ten Guineas per annum.

Mr. May proposed that Messrs. Price, Waterhouse & Co. be appointed auditors for the ensuing year at a fee of Ten Guineas.

Mr. Ockenden seconded the motion, which was carried.

The President then announced the result of the Ballot to fill vacancies on the Council, as follows:—

Four members retired—Dr. A. E. Dunstan, James Kewley, Professor W. W. Watts and Mr. E. H. Cunningham-Craig. Those

four gentlemen had offered themselves for re-election and they had all been re-elected that afternoon, so there were no new members on the Council. There had been three other nominations, but they had not secured election.

The President said he had great pleasure in announcing that owing to the generosity of Mr. Alexander Duckham, a Medal would be offered to be designated the Redwood Medal. It would have a bas-relief of the late Sir Boverton Redwood's head on one side and a blank on the other side for the name of the gentleman to whom it was awarded. It would be given to the author of the paper of the greatest merit presented to the Institution during two consecutive Sessions. Preference would be given to original work. The Award would not be confined to members of the Institution. It would be a Medal which would be greatly valued and would carry a good deal of kudos. The thanks of the Institution were due to Mr. Alexander Duckham for such a very generous gift. (Applause.)

PRESIDENTIAL ADDRESS.

The Engineer in Relation to the Petroleum Industry.

By H. BARRINGER, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng.

ENGINEERING in all its branches holds such an important position in the Oil Industry that no apology is necessary in putting before you a few notes which, although of necessity somewhat superficial when dealing with such a wide subject in an address, will, I trust, be of some interest.

The first problem in the winning of oil is to locate the field in which there is a prospect of finding oil. Here the geologist is the first man on the ground, but probably he will find the engineer useful in assisting in surveys, together with his advice as to the facilities for transporting drilling machinery, etc., to the proposed site and also, which is most important, the means to be adopted in transporting the oil when found to the various markets, and the cost of doing so.

There are no doubt many places where oil might or has been found in which, owing to their location, it would not be a satisfactory commercial proposition to attempt to work the fields under the prevailing conditions.

Provided conditions are satisfactory and the geologist has decided upon the position of the test boring, the first operation is to put down a trial hole as cheaply and as quickly as possible, as unless it is definitely known that oil exists and can be economically obtained, which is seldom the case, it would not be advisable to incur greater expenditure of capital than that absolutely necessary until the presence of oil in satisfactory quantities is proved.

It is desirable whilst this trial boring is being made to go closely into future requirements with the idea that oil *will* be found and the field developed, so that immediately this is proved it will be possible to at once proceed with the equipment. It will also have to be decided, probably before the trial boring is commenced, what system of drilling is to be adopted, although possibly, owing to experience gained with the first bore, it may be thought advisable with future borings to adopt a different method.

The systems of drilling may broadly be divided into two classes—the Rotary and the Percussion. In shallow wells the auger is sometimes used, which, of course, is rotary in its action; but with this exception in the rotary class a stream of mud- or clay-laden water is introduced by pumping from the surface through the hollow drill-pipe and tool with the object of clearing away the detritus removed by the drill. The clay-laden water is also useful in plastering the sides of hole and preventing caving in. No core can be secured, but by careful examination of the water returned to the surface a very good idea of the formation of strata through which the drill is pressing can be obtained.

A further development of the rotary drill is now coming into use consisting of a double tube drill, the annular space between tubes being used for the water circulation, thus allowing a perfect core to be obtained from the inner tube.

In the event of passing through hard material with the rotary system a diamond, shot, or disc cutter drill can be used and a core obtained. But as a rule there is little use for the diamond drill in oil work.

Another advantage of the rotary system is that joints can be made and broken mechanically.

Rotary drilling machinery has now been brought to a high state of efficiency, due to much experience and careful thought in design.

In the percussion system drilling is accomplished by drills attached to a walking-beam either by poles or flexible cables, the beam being operated in order to give a reciprocating movement giving a continuous series of blows. The action being practically the same in both cases, the essential difference being in the connection of tools with surface, being in the first case by poles and in the second case by cables. In the pole system, generally known

as the Canadian, ash poles were commonly used, but these in late years have been displaced by iron bars ¾ in. to 1¼ in. diameter. The advantages of this system may be summed up as: less experience required, especially in comparatively shallow wells; less difficulty in boring a true hole; and, generally, the gear required is less cumbersome than that of the cable system.

The cable system, known as the Standard, has many advantages, especially in prospecting work, and most of that done recently in America has been accomplished with this system. The cable mostly favoured, except for very deep holes, is generally Manilla 1¾ to 2¼ ins. diameter. Steel cable is, as a rule, only used in deep bores.

A system known as the "Freefall" has been much and is now used in Russia, allowing a free fall to tool and string at top position of beam. This is somewhat cumbersome and unwieldy, but has grown up with the developments of the fields and is not easily displaced.

In all drilling work it is of the greatest importance to secure the best material and tools of proved efficiency. This may add to first cost but will be found the most economical in the end.

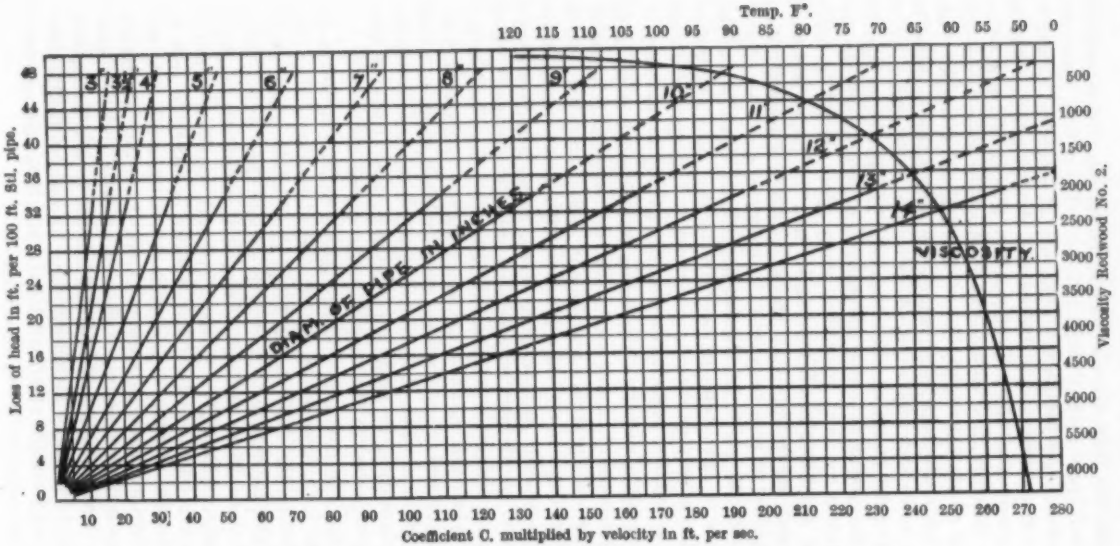
Power on Oilfields.—Hitherto steam has been the principal source of power employed in carrying out the usual operations on the oilfield. Steam has its advantages in being very flexible in its application and easily attended, and in the case of cable or pole drilling is generally preferred, although the difficulties with the electric drive in these operations have been practically overcome and no doubt the prejudice in favour of steam will in time disappear. The disadvantages attending the use of steam are important. In the first instance the matter of transport of boilers and machinery to the site is often a laborious and difficult task. Moreover, the consumption of fuel on the field in some cases is almost incredible, amounting to about 120 lbs. per horse power, largely due to condensation in the long lengths of inadequately lagged steam-pipes, together with the uneconomical type of prime mover and the multiplication of units. Moreover, fresh water is not always available for boilers.

By the use of the electrical drive the difficulty of transport is reduced by the use of large power prime movers, either internal combustion or steam, it being possible to assemble the whole of the power generating plant as a central station in the most favourable position, the conveyance of electrical power over long distances to all parts of the field being cheaply and quickly installed. There are now several fields electrically equipped and others in process of conversion, and there is no doubt as to the economy which will be attained.

Pumping on the field can also be carried out more economically with electrical power than with steam. There are, however, several disadvantages attached to the use of electrical power in boring operations, owing to the difficulty of obtaining instantaneous variations of speed within wide limits, but this should not be an insuperable difficulty, and in some cases has now been overcome. The free use of clutches might be of assistance, particularly the Hele Shaw hydraulic type, with which the motor can be freed or engaged instantly and any required reduction of revolution from the constant speed motor can be obtained. The saving of fuel by assembling the power in a central station, together with its distribution electrically, is so great that every effort should be made to overcome the difficulties attending its use. A paper was read at our last meeting dealing with the application of electricity on the field, which goes very fully into the question and is worthy of close study. In the particular field dealt with the flexibility of the motor appears to have been successfully secured, and the use of gas-fired boilers supplying superheated steam to high speed turbines at a central generating station has proved entirely satisfactory.

Attention is often called to the waste in using oil in place of coal for the purposes of raising steam, but probably more waste of oil takes place on the field than in any other direction. It is possible in some cases to use the oil engine with direct transmission of power without the introduction of electrical generators and motors. Again, gas engines may be and are advantageously used where a constant supply of gas is available, or gas-fired boilers can be employed when the use of steam is advisable. Compressed air has also been suggested, and in some cases tried, in order to avoid the wasteful condensation of steam, but air compressors require considerable attention to maintain efficiency, and there is also trouble to be expected in the freezing-up of pipes, etc.

Before leaving the field a few words should be said in reference to casing. It is, of course, of the utmost importance that the casing supplied to the field should be of the highest quality and suitable for the particular locality. Seamless, hot rolled, high tensile steel tubes—35 to 40 tons—when well manufactured form excellent casing. They give greater strength against external pressure, and if required to be drawn are not so likely to part at the screwed joints. It has been found that with mild steel the socket is liable to expand and allow thread to draw, sometimes with very considerable damage to the thread itself. Joints have been known to draw with a pull of about half the tensile strength of the main body of casing. It is impossible to make a satisfactory lap weld with high tensile steel, but by the Mannesmann process a reliable seamless rolled tube can be obtained.



Loss of Head per 100 *ft. steel pipe with heavy Mexican oil of given viscosity.*

Note.—For suction piping, the total loss including lift, if any, must not exceed 34 ft.

To find loss of head per 100 ft.:—
(1) Multiply velocity in ft. per sec. by coef. C.
(2) Read from base line to diameter.
(3) Horizontally read head.

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(1) Multiply velocity in ft. per sec. by coef. C.
(2) Read from base line to diameter.
(3) Horizontally read head.

Temp. F.	T	60	65	70	75	80	85	90	95	100	105	110	115	120
Coefficient	C	39·35	28·21	20·78	15·66	11·51	8·5	6·2	4·7	3·6	2·75	2·21	1·92	1·7

Diam. in inches.	Velocity, feet per second. Tons per hour.																		
	0·5	0·6	0·7	0·8	0·9	1	1·5	2	2·5	3	3·5	4	4·5	5	5·5	6	6·5	7
3 ..	2·3	2·76	3·22	3·68	4·14	4·6	6·9	9·2	11·5	13·8	16·1	18·4	20·7	23	25·3	27·6	29·9	32·2
3½ ..	3·13	3·75	4·38	5·0	5·63	6·26	9·39	12·5	15·6	18·8	21·9	25	28·2	31·3	34·4	37·5	40·7	43·8
4 ..	4·08	4·9	5·72	6·53	7·35	8·17	12·25	16·34	20·4	24·5	28·6	32·7	36·7	40·9	45	49	53·1	57·2
5 ..	6·38	7·65	8·93	10·2	11·5	12·76	19·14	25·5	31·9	38·3	44·7	51	57·4	63·8	70·2	76·6	83	89·3
6 ..	9·19	11	12·86	14·7	16·5	18·38	27·6	36·8	46	55·2	64·4	73·6	82·8	92	101	110	119·5	128·6
7 ..	12·5	15	17·5	20	22·5	25	37·5	50	62·5	75	87·5	100	112·5	125	137·5	150	162	175
8 ..	16·35	19·6	22·9	26·1	29·4	32·7	49	65·4	81·8	98·1	114·5	131	147	163	180	196	212	229
9 ..	20·7	24·8	29	33·1	37·2	41·4	62·1	82·8	103·5	124	145	165	186	207	228	248	269	290
10 ..	25·5	30·6	35·7	40·8	45·9	51	76·5	102	127·5	153	179	204	230	255	281	306	332	357
11 ..	30·9	37	43·2	49·4	55·6	61·8	92·7	123·6	154	185	216	247	278	310	340	370	402	432
12 ..	38·7	44·1	51·4	58·8	66·1	73·5	110·2	147	184	220	257	294	330	367	404	441	478	514
13 ..	43·1	51·7	60·4	69	77·6	86·3	129·4	173	216	259	302	345	388	431	475	518	561	604
14 ..	50	60	70	80	90	100	150	200	250	300	350	400	450	500	550	600	650	700

Great care should also be taken in the cutting of the screw threads and maintaining correct gauge.

There are several formulæ for deciding the thickness of casing for certain diameters and depths.

Stewart's formula gives :—

$$P=(1-\sqrt{1-1600\ \frac{t2)}{D^2}}\ \text{for tubes where}\ \frac{t}{D}=\text{less than 0·023, and}$$

$$P=86670\frac{t}{D}-1386\ \text{where}\ \frac{t}{D}\ \text{exceed 0·023.}$$

P = Collapsing pressure.
t = thickness tube.
D = Diameter in inches.

Calder gives an empirical formula based on above for thickness of pipe :—

$$t=\frac{P.\ F+1386}{86670}\ x\ D$$

where t = thickness of tube.
P = Hydraulic pressure due to depth + 1/3.
F = Factor of safety.

Although not carried out in all cases, it appears advisable to allow a factor of safety of at least 2, and any extra strength obtained theoretically by the use of high tensile steel should be taken as an additional safeguard, as the calculated pressure at any depth is liable to be greatly exceeded by the pressure of boulders, which may set up a severe local pressure.

Oil having been won on the field, the next problem for the engineer to solve is to transport the oil either in its crude or refined state to the locality for consumption or to refineries. Pumping through pipe-lines is the most convenient, and in the majority of cases the most economical, although in localities where a large and constant supply is not assured a costly outlay on pipe-lines and pumps may not be thought advisable. There are now in the United States some 45,000 to 50,000 miles of pipe-lines, which are constantly being added to, in addition to which great quantities of oil are transported by rail tank-wagons and by barges or small craft on the waterways. In long pipe-lines flexible cylinders provided with spring scrapers, usually known as "Go Devils," are often pumped through the lines with the oil in order to remove any deposit forming on the internal surface of pipe. At the end of a stage these drop into a box, below and clear of the line, from which they can be removed, cleaned and returned for another journey.

The handling of gas from the field and the transport to centres of consumption is another operation that calls for the skilful attention of the engineer.

Pumping is such an important operation in the handling of oil that I propose to go a little more closely into some of the conditions met with.

On the field, in refineries and storage installations, where the distances dealt with are comparatively small, the duplex direct-driven steam-pump is mostly favoured. This is on account of its giving a steady discharge, etc., easy handling, flexibility and general reliability, but it is by no means economical in its consumption of steam. Power pumps, either electrically operated or driven by internal-combustion engines, are in some fields displacing the steam pump, but as steam is generally required for some purposes the steam pump is likely to survive for some time in refineries and storage installation. Without doubt in many cases sufficient care is not exercised in the design of pumps. Suctions should be as large and as short as possible. All passages well rounded and free from pockets, etc., likely to set up eddies, valves and seats with ample area and without obstructions to the easy flow of oil, even a small obstruction in the valve seats, cross guide bars for instance considerably affects the efficiency.

All stop valves should be of the throughway gate type with edges rounded, bends avoided as far as possible, but if necessary of large radius. Although these requirements are important in all pumps, they are especially so in the case of large pipe-line pumps working under high pressures and dealing with large outputs.

These pumps up to the present are generally steam driven either duplex or single, and compound or triple expansion, and if water is available condensing. For high pressures the plunger type of pump is sometimes preferred, but if the barrels and pistons are carefully ground to a fit, the pistons being solid, of ample depth and with circumferential grooves, excellent results and high efficiency can be obtained. The excessive friction with packing in large plungers is avoided, and there is also the advantage of being able to make pump double-acting. The three or more throw plunger pumps, however, give a very steady flow. Air vessels of large capacity are indispensable with high pressures, together with compressors to make up the loss of air by absorption and keep them fully charged.

In order to ascertain the probable loss of head through internal friction of pump or fittings the following experiment was made :—

Water was the medium employed, 99 tons per hour being pumped through a 10-inch line, 93 miles (491,040 feet) in length. It was found that the theoretical pressure required to fulfil these conditions

through a straight pipe was exceeded by about 13 per cent. It may be therefore taken that this extra power was principally necessary to overcome the friction through valves and fittings surrounding pump. These figures point to the importance of ample margins when dealing with pumping problems; with heavy viscous oil the loss would have been greater. In connection with actual pumping data experiments carried out by Messrs. Weir with Mexican oil are of great interest, demonstrating clearly the the influence of temperature and viscosity on the flow of oil. For instance, it will be seen that taking a 14-inch pipe, with oil at temperature of 60° F. and a viscosity of 2450 velocity of flow 4 feet per second=400 tons per hour, the loss of head was 20·8 feet per 100 feet of length, but with oil at a temperature of 120° F. viscosity 120 the loss was only 0·9 feet per 100 feet. Again, taking an 8-inch pipe, velocity 3 feet per second=98 tons per hour at a temperature of 60° F., the loss of head was 46· feet per 100 feet length, but with temperature 120° F. the loss was only 2·2 feet. From this diagram it is at once seen what an important bearing the viscosity varying with the temperature has on the flow of oil and therefore the power required in pumping. The advantage of employing a large pipe will also be noticed. This is, of course, what would be expected owing to the oil adhering to the internal walls of the tube, and thus restricting the effective area of cross section of pipe. With heavy viscous oil a comparatively small column of oil moves at the highest speed, the actual velocity of the oil gradually diminishing from the centre to the circumference, where a film of oil adheres to pipe and moves slowly and as the area of cross section of pipe varies as the space of the diameter. There is a greater proportion of oil moving at normal velocity the larger the diameter of the pipe.

14-inch pipe = 400 tons per hour. V. 4 feet.
60° F. 4 × 39·35 — 157·4
157·4 by curve 20·8 feet loss head in 100 feet.
at 120° F. 4 × 1·7 = 6·8
6·8 by curve = ·9 feet of head in 100 feet.
8-inch = 98 tons per hour. V. 3 feet.
60° F. 3 × 39·35 — 118
118 by curve 46 feet loss head in 100 feet.
120° F. 3 × 1·7 — 5·1 by curve 2·2 feet loss of head in 100 feet.

A formula I have found useful, based on Kutters for water and adapted to oil gives :—

$$Q = \frac{C\sqrt{P}}{L.\ G.}$$

Q. Quantity in barrels 42 U.S. gallons.
C. Constant varying from 25 to 338, according to size of pipe.
P. Pressure at pump.
L. Length of pipe in miles.
G. Specific gravity.

In an endeavour to overcome this difficulty the rifled pipe was introduced. This is rolled with large, well rounded corrugations arranged longitudinally in spirals, the object being to impart a rotative motion to the oil passing through. By introducing with the oil a small percentage of water, this being heavier is thrown out to the internal circumference of pipe, and there forms a film of water acting as a lubricant to the oil passing through and preventing it adhering to the walls. It is difficult to obtain reliable results, but this form of pipe does not appear to have made much headway or to have been extensively adopted.

It will be noticed that in the long distance pumping data Weirs' formula gives too great a loss of head. This is due to the oil being of a totally different class to the Mexican with which experiments were made; also there are many complications arising in long distances, such as gradients and variations of temperature, so that each particular pumping problem should be carefully studied both theoretically and in connection with known results obtained by experience.

The tanker pumping data over short distances, it will be noted, agrees more closely with the curves. It may be of interest here to introduce some pumping results obtained under ordinary working conditions both on long lines and on tankers.

The operation of refining covers such a wide and varied field that only a brief reference can be made to this section, although the chemist and engineer are very closely allied, the former constantly seeking more effective methods for the production of the requirements and the latter striving to devise new and more economical apparatus for the carrying out of the chemist's wishes, often for experimental purposes having to deal with very high pressures, and it is upon their efforts that the advancement of the technology largely depends. Retorting apparatus is also receiving special attention at the present time, and various types are now under trial. The question of lubricating oil is, of course, of paramount importance to the engineer, and this is a matter where the chemist and engineer are again in close touch.

For oversea transport the tank steamer is so well known that it is not necessary to refer to it in detail. It may be mentioned that there are now vessels afloat carrying over 18,000 tons of oil in bulk, and Lloyd's give a list of more than 1000 tankers in commission

PUMPING DATA.

Class of oil	Temperature of discharge. ° F.	Specific gravity.	Size of pipe-line. in.	Length of pipe-line. ft.	Pressure at pump. lb. per sq. in.	Velocity of flow. ft per sec.	Tons pumped per hour.	
Mexican	110	0·950	8	84,400	800 to 850	5·18	159	—
Burmah	85—90	0·850	4	170,000	1125	2·7	21	During day.
Burmah	Various	0·850	4	170,000	1200	1·33	11·8	During night.
Burmah	100	0·850	4	168,960	600	2·2	16·7	—
Burmah	85	0·850	8	10,050	150	3·2	98	—
Burmah	85—90	0·850	8	21,120	65	3·8	116	—
Burmah	80	0·850	8	20,000	80	3·6	112	—
Burmah	82	0·850	10	475,200	450	2·4	118	—
Burmah	82	0·850	10	723,360	400	1·5	74	—
					Pump 10 in. × 30 in. Single double acting.	16½ in. × 25 in. × 36 in. 30 in. stroke.		Pump on long lines Cylindrical.

ACTUAL PUMPING EXAMPLES—TANKERS.

Showing effect of temperature and viscosity on discharge.

Mexican oil.

Class of oil.	Viscosity Redwood No. 1.	Temp. of oil. ° F.	Specific gravity.	Size of shore line. in.	Length of line. ft.	Pressure at pump. lb. per sq. in.	Velocity of flow. ft. per sec.	Tons pumped per hour.
Flux	40,000 @ 100° F.	130	0·980	8	2000	77	1·4	47·5
Flux	40,000 @ 100° F.	130	0·980	8	2500	80	1·8	63
Flux	40,000 @ 100° F.	150	0·980	10	200	25	6·7	356
Fuel	1500 @ 100° F.	70	0·852	8	2500	85	4·2	126
Fuel	400 @ 60° F.	55	0·908	14	400	40	4·6	448
Fuel	400 @ 60° F.	100	0·908	15	500	40	4·5	472

with a gross tonnage of about 4,830,000 and 140 sailing vessels with 145,000 tons.

The general design of the tank vessel has not altered materially within recent years, and the longitudinal system of framing is adopted in practically all ships carrying oil. The general tendency is to enlarge the pumping power, upwards of 450 to 500 tons per hour being discharged through one shore line.

In the matter of propelling machinery many vessels have been fitted with steam turbines, using superheated steam running at high speed and driving through double reduction gearing, the boilers being oil fired.

In some cases trouble has been experienced with the reduction gearing. Suitable material and extremely accurate cutting of teeth are essential to secure satisfactory running.

The internal-combustion engine is attracting more attention every year. There have lately been marked improvements in design. Several tankers have been fitted with this type of machinery and are doing good work, but accurate data in reference to upkeep are difficult to obtain. The double acting four-cycle is one of the latest developments. Trials of the opposed piston type have also been very successful. Although there is no doubt as to the economy in consumption of fuel, it must be borne in mind that commercially there are several factors to be considered. In the first place the cost of Diesel engines is greatly in excess of that of steam machinery. This means that the initial cost of vessel is greatly increased. Insurance and interest on capital is proportionately heavier, and although the weight of fuel burnt is less, and therefore bunker requirements can be reduced, thus allowing vessel to carry extra deadweight, the cost of fuel is much higher, and although number of firemen is reduced more greasers are required and the engineering staff larger than required in the same powered steam-driven vessel. It is also usual to fit an auxiliary boiler to handle steering gear, windlass, winches, etc., and to supply steam for steaming out tanks and for heating cargo if of a heavy and viscous nature. In some cases where possible electricity is employed, but all these auxiliaries add to first cost and require skilled attention. Consumption of lubricating oil is also heavy. It is not possible to speak definitely as to cost of upkeep, but undoubtedly it will be heavier than with steam.

All the above costs must be taken carefully into account before the question of commercial economy can be definitely settled.

One of the largest and most important branches of engineering connected with the industry and immediately concerned in the use of the refined product is that of the automobile engineer. This will readily be realised when it is remembered that in this country

there are now about 1,080,000 licensed vehicles, comprising heavy lorries, commercial vehicles, agricultural implements, omnibuses, taxis, private cars, and motor cycles. This number is of course only a very small proportion of the world's total, which is computed at nearly 18,000,000, 83 per cent., about 15,000,000 being located in the United States, the output of new cars last year in the States being returned as 4,000,000. With every year showing an increasing output the question of high compression in order to increase power is at the present time constantly engaging the attention of the chemist and the refinery engineer. The problems to be solved are exceedingly complex, but considerable advance has been made towards their solution. Engineers—especially those engaged in aero-engine work—are constantly asking how to specify a fuel which will best stand the high compressions aimed at without detonation. With our present knowledge this is not possible, but it is a question requiring close study and experimental work.

The storage of oil, especially in installations engaged in the distribution also, demands the very careful consideration of the engineer. The methods of delivery from stock, which may comprise pipe-lines, road, rail, canal and river, in bulk, barrels and cans, must all be studied and the lay-out of ground arranged so that one operation does not interfere with another. Foundations for tanks are an important matter, especially on soft and swampy ground, which often prevails in situations selected as storage depots.

The tendency is at the present time to construct tanks of larger capacity, 100 to 130 feet in diameter. In the United States storage tanks are now practically standardised, but scantlings are inclined to be somewhat on the light side compared with British practice. The matter of fitting lightning conductors to tanks has also lately occupied the attention of engineers, but it is open to doubt as to whether these are of value, and in some cases it is possible might be a source of danger. In the opinion of several authorities it appears that if tanks are properly earthed there is little cause for anxiety; it is also advisable to well earth all pipe-lines.

Pipe-lines, both for reception and delivery of oil fuel, require to be heated, which is best done by running a steam pipe through centre. It is now the general practice to connect the storage tanks to pipe-lines by flexible hose to allow for movement. The metallic spiral interlocking type being most favoured, although more easily damaged it is less cumbersome and with care lasts longer than the fabric hose.

Steam power for pumping, etc., is generally adopted, but electrical power is also used, in some cases care being taken to avoid

danger from sparking. When spirit is received from vessels, steam is supplied from shore to actuate ships' pumps, no fires being allowed on board during period of discharge.

Where canning of petrol is carried out special machinery is in use for this purpose, and has been brought to a high state of efficiency for rapid operation.

In the United States the delivery of petrol for use in automobiles is almost universally carried out by roadside pumps, and the same practice is rapidly finding favour in this country. It has the advantage of saving the cost of cans and filling, and spirit can be more easily transported in bulk. The prejudice against this means of supply is gradually being overcome. The brand of petrol is guaranteed, and generally the storage tanks are sealed, and if pumps are kept in proper order correct measurement is always obtained.

The question of pumping the oil-contaminated water discharged from ballast bilges and bunker drainings overboard has also lately required attention. Several systems have been devised for extracting the oil, generally depending upon a series of weirs and baffles, together with reversals of the flow and the difference of specific gravities. Steam coils are also introduced in some cases to finally clear the effluent. Owing to the recent action of various harbour authorities, prohibiting the discharge of oil-polluted water in harbours, rivers, docks, etc., this question has become important. Even where a vessel proceeds to sea outside the three-mile limit to discharge ballast, etc., the oil pumped overboard with the water in many cases finds its way eventually to the coast and is deposited on the shore. In the large liners burning liquid fuel, where in some cases it is necessary for purposes of stability to replace oil burnt by water, there is also often a considerable loss of oil when emptying bunkers of water before replenishing stock of fuel. The procedure most favoured is to provide barges fitted with an accepted purifier mounted on board for the use of vessels using the port and requiring to dispose of contaminated water.

Although all machinery used in the various operations is naturally capable of improvement in several directions the engineer's attention is called specially to the following:—

Economy on the Field.—There is wide scope for improvement here. In the first place the elimination of steam power in small units and also in central power stations, except possibly where an ample supply of gas is available not otherwise valuable.

The close study of the electric motor, especially in reference to its adaptation to boring operations.

The examination and selection of the best materials for tools, drilling poles, casing, etc., and the careful design and manufacture.

The better attention to and care of drilling gear and other machinery on the field. This is often found in a very neglected and dirty condition.

In the matter of prime movers the development of the Diesel or other internal-combustion engine comprising the possibilities of larger powered units. The selection and improvement of metal used in castings and valves and reduction in the cost of manufacture. In the petrol engine the adoption of higher compressions and increase of revolutions tending to reduce the weight per horse-power developed, and improvements in the apparatus used in retorting and refining and generally affecting all these items. The question of standardisation as far as possible.

Professor J. S. S. Brame said it was with very great pleasure that he moved a cordial vote of thanks to the President for the very comprehensive address which he had given on the Relationship of the Engineer to the Oil Industry. It was not usual to discuss Presidential Addresses, and, of course, he would follow precedent in that matter, but he did feel that the President had touched on a very large number of topics which were so suggestive that he hoped the Institution would have papers in which those topics would be elaborated at no distant date. Then the members would have the opportunity of hearing the President take part in the discussion and of taking part in it themselves. He begged to move a hearty vote of thanks to the President for his Address and to ask the President's permission for it to be printed in the Journal of the Institution.

The vote of thanks was carried with acclamation.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

Annual Dinner.

THE Sixth Annual Dinner of the Institution of Petroleum Technologists was held at the Connaught Rooms, Great Queen Street, London, W.C. 2, on Tuesday, March 18, 1924, the chair being taken by the President, Mr. H. Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A.

The guests of the Institution were :—Major-General Sir W. S. Brancker, K.C.B., A.F.C. (Royal Air Force), Mr. R. Gilman Brown (President), Institution of Mining and Metallurgy), Mr. H. G. Burford (President, Institution of Automobile Engineers), Mr. A. W. A. Chivers (President, Diesel Engine Users' Association), Mr. J. C. Clarke, C.B.E. (Petroleum Department, Board of Trade), Mr. H. Edwin Coley (Chairman, Chemical Industry Club), Engineer Vice-Admiral Sir Robert B. Dixon, K.C.B. (Engineer-in-Chief of the Navy), Dr. Bernard Dyer (Chairman, London Section, Society of Chemical Industry), Mr. W. St. D. Jenkins, C.B., C.B.E. (Director of Navy Contracts), Mr. C. le Maistre (Secretary, British Engineering Standards Association), Mr. G. Patchin (Sir John Cass Technical Institute), Sir Joseph Petavel, K.B.E. (National Physical Laboratory), Mr. Arnold Philip (Admiralty Chemist, Portsmouth), Major R. Rigg, O.B.E., J.P., Mr. W. C. Sneath (Honorary Auditor), Admiral W. Stokes-Rees, C.B., R.N., and Mr. W. J. U. Woolcock, C.B.E. (General Manager, Association of British Chemical Manufacturers).

"THE KING."

The President proposed the toast of "The King," which was accorded musical honours.

"THE SERVICES."

Prof. J. S. S. Brame : Mr. President and Gentlemen,—I have the honour to propose the toast of "H.M. Services." Mr. Ashley Carter, in arranging what I might call a short curtain raiser, asked me if I would propose this toast. He pointed out to me that I had had a long association with the senior Service, extending over some twenty-seven years, and that possibly such a toast as this might well come from me. Gentlemen, I feel indeed

that we ought to make the most of it, because one or two recent speeches—very recent, I may say—rather foreshadowed that the Services may not be always with us, and in our dotage we may say to our grandchildren: "Ah, in those good old days we used to drink the health of the defenders of our country." It may be a long time before we welcome at our banquets the Secretary of State for Peace, but we have always been very pleased to welcome First Lords of the Admiralty, Secretaries of State for War, and Secretaries of State for Air. There is always this consolation that threatened lives are usually the longest lasting, and we may hope it is so in this particular case.

I do not know that I need dilate upon the connection between oil and the Services. It certainly is well known to all Petroleum Technologists, and the Services recognise the assistance rendered by the Petroleum Technologists to the Services. We have always had the pleasure of welcoming at our Annual Dinner very distinguished representatives of the Navy, the Army, and the Air Force, and I would like to add also the great non-combatant service, the Civil Service, because we are very closely connected through the Civil Service with the supply of oil to Government Departments. It is a very great pleasure to us to welcome to-night, as we have on previous occasions, the Director of Contracts and the Director of Stores from the Admiralty. The Navy is almost dependent on oil in these days. "Old King Coal was a dirty old soul," and the less the Navy had to do with him in the future the better they will like it. At one time the sailor man had only one use for oil, and that was to pour it on the troubled waters; but to-day he knows that—thanks to some recent legislation—if he pours it on harbour waters it leads to trouble. I always try to impress upon the naval officers who are under my tuition at the Royal Naval College at Greenwich that water is the sole support of the Navy. (Laughter.) I always add a corollary to that: that although it is the sole support they are dependent on oil. The association of the Army with oil is very extensive to-day. Troops, food and ammunition are transported by means of oil. Heavy guns are pulled along by oil tractors. The recoil cylinders of the guns are filled with oil. The tanks are driven with oil. Oil even supplies material for explosives. So there is a very close connection between the Army and the Institution of Petroleum Technologists. I think it was Napoleon who said that an army marched on its stomach; but to-day an army is transported by oil. When we come to the Royal Air Force, does not that owe its birth to oil? Could we have mastered the problem of flying had it not been for oil? The invention of the petrol engine made flying a possibility, and flight has transformed the whole question of warfare. It has added new problems to attack, and new problems—and very

anxious problems—to defence. It has broken down the barrier that for centuries existed between ourselves and possible enemies—the barrier of the sea, which, with the aid of a powerful Navy, was the great defence of this country. We have to look to the Air Force to provide an adequate defence against modern attack. I am sure that what little I have said as to the connection between the Petroleum Technologists, and oil, and the Services is quite sufficient to introduce the toast to you. The producer and refiner of oil fully realise their responsibility to the Services, and I am quite sure it will be a very hearty response which the members of this Institution will give to the toast which I have the honour of proposing this evening, "The Services," coupled with the name of Engineer Vice-Admiral Sir Robert B. Dixon.

The toast was duly honoured.

Engineer Vice-Admiral Sir Robert B. Dixon, K.C.B.: Mr. President and Gentlemen,—At the Dinner of the Institution last year I had the honour of replying to this same toast. I hope, therefore, you will forgive me if, during the course of my remarks, I refer to some of the points that were then touched upon. The Services are dependent to an ever-increasing extent on petroleum and its products. The uses of oil by the Army, the Navy, and the Air Force have been referred to by Prof. Brame, and need not be repeated; but the Navy is by far the larger individual user, not only among the Services, but also in the British Empire. Therefore—and not unnaturally, perhaps—the Admiralty is subject to a certain amount of friendly criticism and advice. This criticism is based, I think, on a wrong conception of the requirements of the Navy, and I should like with your leave to refer to it. We are accused, in the first place, of what I might almost call criminal waste by burning oil under boilers; and secondly, of taking a lukewarm interest in the development of the oil engine for marine purposes. Now, what are the facts? Practically every warship of any fighting value has a speed of over twenty-one knots, and a great number have a speed of over thirty knots. This is in rather striking contrast with the Mercantile Marine, where the total number of sea-going vessels that steam over twenty-one knots—and I do not include the cross-Channel steamers—probably does not exceed twenty, and certainly not more than twenty-five in the whole world. Now naval architects have done very great things in developing the high-speed steamship, but nevertheless, in the present state of the art, high speed entails exceedingly high engine power, the aggregate of which, when divided to the very greatest possible extent which the design of the ship permits, necessitates for each propeller shaft a horse-power varying from 36,000 in a battle cruiser to 13,500 in a destroyer.

Now, granting the durability and reliability of the Diesel engine, this power is very much in excess of anything that has yet been fitted to a ship. Again, the weight of the marine Diesel engine, even allowing for the very much greater economy, is very excessive compared with that of the steam installation. We see frequently—indeed, almost every week—accounts of trials of motor ships of moderate power, ships which, I believe, have run very successfully on service; but the weight of the machinery of those ships—by weight of machinery I include the whole machinery, accessories and shafting—varies from 250 lb. to 350 lb. per shaft horse-power compared with the weight of machinery of steam installation of 80 lb. in a battle cruiser, and 33 lb. in a destroyer. As an example which will show the comparison very well, I think the weight of machinery of a motor ship of 3000 horse-power is just about equal to the weight of steam machinery and boilers in a destroyer of 27,000 horse-power. It is obvious, therefore, that if the oil engine is to be fitted in warships the weight must be very much less than what has been found to be satisfactory in the Mercantile Marine. Some advance may be expected by a change of type, and in this respect the double acting two-cycle design offers the chief hope of obtaining a higher power on a reasonable weight basis. It is in this direction that we are carrying our research work at the Admiralty Engineering Laboratory with a view to increasing the power obtainable on a weight basis that is acceptable, and increasing that power very much above anything that has yet been attained either in the Mercantile Marine or in the Royal Navy. It is unfortunate in this connection that we are unable to take full advantage of the experience of the engine builders of the country, because the requirements of the Naval Service differ so materially from the requirements of the Mercantile Marine Service. It is particularly unfortunate because the engine builders and shipbuilding firms of the United Kingdom always place at the disposal of the Admiralty all the experience that they gain in the development, not only of the marine Diesel engine, but of any other form of engine.

I am afraid that during my remarks I have hardly referred to the other Services, because in the presence of so many distinguished officers of those Services, I do not feel very competent to do so. But I think I can say without fear of contradiction that all the Services owe thanks to this Institution for the work it is carrying out, particularly in respect to the standard classification and specification of various classes of oil, and I feel sure that I can speak with great confidence on behalf of the Services in thanking Prof. Brame for his speech in proposing the toast, and also you, Gentlemen, for the cordial way in which you have honoured it. (Applause.)

"THE PETROLEUM INDUSTRY."

Sir Westcott S. Abell, K.B.E.: Mr. President and Gentlemen,—I am under the impression that the ancient history of the petroleum industry has not yet been written. I am very interested in archaeological studies myself, but not in that particular direction. I think, however, that if some of you would search the Old Testament you would probably find some references to this ancient industry. It might be argued, for example, that Elijah's success in firing the burnt sacrifice when the priests of Baal failed might have been due to the fact that he struck oil somewhere and knew the uses of it. (Laughter.) There is a further reference that I discovered in regard to the widow's cruse of oil which always remained filled. When I learned that that incident occurred in Sidonia, it occurred to me that it might be a satisfaction to some of the members of this Institution to know that they might have as good a chance of prospecting in that region as in some parts of the United States from which we have recently had very attractive circulars. (Laughter.) However, my studies proved that the references were very scanty and my attention must be confined, therefore, rather to the present aspect of the problem. To my mind, a non-expert mind, the advance which has been made in the last generation is really marvellous. I think I am right in saying that some thirty years ago, a mere generation ago, the total production of oil in the world was only 10,000,000 tons. Last year I believe it had risen to some thirteen times that amount. As to the present rate of increase, I read the other day that the production in the United States in 1923 was something of the order of 115,000,000 tons, or 5 per cent. more than the rest of the world in 1920. That will give you some idea of the rapid growth and of the magnitude of the industry. To my non-expert mind also the part played by Petroleum Technologists in this development is not understood by the public nor appreciated in the way that it ought to be, because if it were not for the part that those gentlemen have played in the separation from the crude oil of the beautiful pure constituents that we see in various forms the oil industry could not possibly have developed at the rate that it has done. There is the beautiful water-white petrol, as well as lubricating oil which may be applied both externally and internally. (Laughter.) I do not wish to bore you with the relative merits of those two as you know all about them. Then also you have paraffin wax, which I was going to say was a staple article of diet (Laughter), and a very humble product, kerosene, which gives light to the country side, to say nothing of the many power products which we depend on in this generation.

One trembles to think what the position of the coal industry

in these islands would have been if oil had been discovered before coal. Certainly, I think we should have had a brighter London, and the prospects for the conservation of the natural resources of this country would have been very much better than they are to-day. On the other hand, if one likes to let one's imagination stray, you may observe that light fiction abounds in remarkable stories consequent upon the discovery of artificial diamonds. I should like to draw a bow at a venture and write a romance which might indicate the consequences arising from the manufacture of petrol from coke—a prospect which I believe is not outside the bounds of possibility.

As such matters as I have referred to are no doubt much more familiar to you than they are to me, I had better confine myself to those aspects of the question with which I am more acquainted. It appears to me that we are witnessing at very close range the substitution of oil for coal as a source of power on board ship. Liquid fuel has so many advantages over solid fuel in matters of transportation that it is idle for me to waste your time in dealing with what I may call the material advantages. There is, however, in addition, the further advantage that we can get three times as much energy from a pound of oil as we can get from a pound of coal, with the consequence that the radius of action of the ship is enormously increased on the same weight. The question of sea transport, to my mind, however, is as much or more one of commercial reliability than a question of technical or thermal efficiency. The future progress of the motor-ship will be measured mainly, I think, by its ability to make use of the cheapest possible fuel and by its reliability in service. It is perfectly evident, as even the most cursory examination will show, that the world demand for oil has enormously increased since the war. In the last four years the amount of oil tanker tonnage in existence has increased 100 per cent. until it is about 5½ million tons to-day. Notwithstanding all that, the activities of the freight market recently have shown that this quantity of tonnage is not sufficient for the world demand. Somehow it does not seem to me that this demand has been altogether foreseen, for when I look at the figures of oil tankers actually being built, I find at the end of 1921 there were about 800,000 tons under construction, while, to-day, there are only something under 200,000 tons being constructed. That is one point as to the demand for oil in the world. The second point that I would like to dwell on for a moment is the motor-ship itself. I should rather gather from the figures of progress that the shipping industry is fairly well satisfied with the efficiency of the motor-ship, but it is naturally somewhat hesitant on the question of reliability. The tonnage of motor-ships in existence has increased by nearly 250 per cent., since July, 1919. But a more

immediate test of the opinion of the shipping industry can be gathered from the figures of ships now being built. At the end of 1922 and at the end of 1923 the total amount of ships building in the world for all purposes was roughly the same—something between 2¼ million and 2½ million tons. Yet at the end of 1922 only one-eighth of that tonnage was being fitted with motors. Twelve months later the proportion has been increased from one-eighth to one-quarter. If you would like it in round figures, at the end of 1922 about 300,000 tons were being built to be fitted with motors and at the end of 1923 the figure was over 600,000 tons. It seems to me that those figures showing this modern development must be very welcome to the shipbuilding industry, for without them the great surplus of merchant shipping tonnage which has existed for the last three or four years might perhaps have gone on for ever.

I have the honour to propose this toast of the "Petroleum Industry," coupling with it the name of Mr. A. Beeby Thompson, a very worthy Member of your Institution, who has a very great reputation in the world for technical knowledge, and also for his great experience. Gentlemen, I give you the toast of the "Petroleum Industry," coupled with the name of Mr. A. Beeby Thompson.

The toast was duly honoured.

Mr. A. Beeby Thompson, O.B.E.: Mr. President and Gentlemen—it is not without trepidation that I rise to respond to the toast of the "Petroleum Industry" before this distinguished audience of petroleum technologists, and it is especially difficult to follow in the footsteps of some of our former petroleum orators, including the late Sir Boverton Redwood, Sir Thomas Holland, Professor Brame, whom we have heard to-night, and Mr. Powell. The industry of which I so modestly represent but a small section is one with which I have been associated for rather more than twenty-five years. My duty has been almost exclusively devoted to the oilfields themselves. There are very few oilfields of the world which I have not visited at some time or other, consequently I have had unusual opportunities of witnessing the many difficulties under which technologists work amidst diversified conditions and unhealthy surroundings. During that interval the oil production of the world has increased from 18,000,000 tons to about 120,000,000 tons per annum. Only a few years ago fears were expressed by responsible American technologists and writers that the production of petroleum in America had reached its zenith, and that unless very stringent restrictions were imposed on its use we were going to see an oil famine. As if to ridicule those prophesies field after field was discovered in rapid succession, and

within the course of about four years the production of the United States had doubled. Nor have estimates of the world's oil production been any more reliable. Nearly every oil-producing country is capable of expanding further its output, and there is a number of proved rich oilfields which have been scarcely scratched to date. I am quite sure that we are not in sight, or nearly in sight, of the maximum productive capacity of the oilfields of the world.

I was unfortunately abroad in some unwholesome part of the world when the last two dinners were held, but I remember on the previous occasion when I was here it was my good fortune—or misfortune—to be entrusted with a very momentous State secret which I think I might be at liberty to divulge at present. The visitor on my right was the Latvian Minister. He told me quite confidentially that his Government had very unfriendly designs on their peaceful northern neighbours, the Esthonians. In fact, they designed to do nothing more nor less than drill a row of wells along the frontier and drain all the oil from the southerly-dipping Esthonian shale deposits, so that our Esthonian friends would have no oil production. I thought the joke too good not to disabuse him of the possibility, and I am sure if he is present to-night he will excuse me having raised a laugh at his expense.

It is not easy to apportion credit for the vast organisation built up by years of hard toil in very many departments and amongst strange surroundings. The explorer, the surveyor, the geologist, the civil and mechanical engineer, the chemist and physicist have all contributed to the realisation of those successful oil enterprises which to-day are the pride of their originators. But perhaps even greater credit is due to the financier and capitalist who, undeterred by all sorts of disappointments, never hesitates to put up money to correct previous costly mistakes and to repair errors. Without money nothing can be done in the Oil Industry. (Laughter.) The richest petroleum deposits have a knack of occurring amidst the most perverse surroundings—always in deserts or amidst tropical malarial jungles. There are only a few places in the world, to which we all try to get, where oil occurs amidst decent healthy conditions. Every conceivable crawling creature appears to conspire against the oil prospector in tropical jungles. Mosquitoes and sand flies worry one by night or even by day. Horse-flies and hornets dodge our footsteps. Tarantulas, scorpions, centipedes and snakes seek shelter in our tents or under our clothes, vampires suck our blood and jiggers get under our toe-nails. In Trinidad we get bete rouge. In Central America we get ticks, in the East Indies leeches, and in Mexico we get bandits. So that really we are prevented from being dull.

I can well remember one strenuous period in Trinidad when three of us out of a party of four went down with a very nasty

dose of fever. Fortunately for the sake of the Oil Industry, the geologist and engineer of the successful type never fail to see the humorous side of hardships, and whether covered with prickly heat, bete rouge, ticks or leeches, or held up by greasy Mexican bandits, they appreciate the humour of the unconventional situation.

To the engineer the Industry owes the development of mechanical devices for the winning, treatment, and handling of oil. To the chemist and scientist the Industry is indebted for their valuable investigations in the constitution of oil and their discoveries of ways and means of producing products best suited for the manufacturer and the arts.

A great deal of irresponsible talk has been directed against the so-called Oil-Rings, and much has been said about the mingling of oil and politics. Upon this latter subject I will say no more than that the recent American disclosures—probably greatly exaggerated by a desire to make political capital out of the trouble—illustrate the extreme danger of Government association with a speculative industry, however tempting the reward. The Oil Industry is big enough and strong enough to stand on its own legs without Government support, financial or otherwise, and the less the interference with the normal processes of trade the better for all. No product is more susceptible to the laws of supply and demand than oil. Recent events following the glut of oil in California and Texas are merely a repetition of the events which have followed the progress of the Industry since its infancy. While the public were temporarily securing oils at the recent low prices they were probably quite unaware that numbers of Oil Companies were brought to the verge of ruin. All but a few producers were not only quite unable to produce oil at a profit, but were even forced to liquidate their stocks of crude oil at very much below cost price. The surest way of encouraging monopolies is by the elimination of independents, and these severe depressions are as harmful to consumers as to the Industry. It must be remembered that the Oil Industry has always been watched, and closely watched, by manufacturers of alcohol, benzol and shale oil. The efforts of conservative oil producers are being constantly frustrated by the get-rich-quick type of speculators, who rush in and acquire lands at any absurd price in newly discovered areas. Recent events in California only illustrate the difficulties with which a cautious operator is faced. Lands are subdivided, leased at fabulous prices and wastefully developed by gamblers in stocks and shares with no consideration to the future. At present there is an international scramble for oil lands. Consumers of oil should realise that the only insurance against an oil famine is an incessant search for new sources of supply to compensate for the exhaustion of the older fields. This involves

risky and expensive exploratory work, and its cost is a charge which the Industry must be prepared to support. This is one of the factors which must always govern the price of oil and tend to keep it up to a generally higher level than formerly. A responsible American Oil man recently made to a committee of industrialists the following astounding statement: that during the last fifty years the American public had been supplied with oil at £500,000,000 below cost, and that in 1922 producers furnished the refining Industry with crude oil at £100,000,000 below cost. This statement is probably not greatly exaggerated if in that figure is included all the ambitious and ill-advised projects as well as the unsuccessful "wild cats" resulting from carefully conceived plans under skilled advice and carried out under strict supervision.

The public may rest assured that those directing our Petroleum policy are working hard to reduce costs and get cheaper products. Under the keen scrutiny of shrewd business men it is not likely that our oil will be recklessly wasted. In conclusion I must thank you most heartily for the enthusiastic way you have received the toast of the Industry and for the kind remarks which were made by Sir Westcott Abell in proposing the toast. (Applause.)

"THE INSTITUTION OF PETROLEUM TECHNOLOGISTS."

Mr. C. S. Garland: Mr. Chairman and Gentlemen,—I am quite sure that I shall have the sympathy of every man here when he realises that, having been brought here without the least suspicion that I was going to be called upon to speak, I have been asked to take the place of Lord Chelmsford. It is the greatest grudge I have ever had, and I have had several, against the present Government. (Laughter.) The discussion of the Singapore naval base, having prevented Lord Chelmsford from being with us this evening, has made me an unhappy victim of his absence. I think I know less about oil than any other man in this room, and that is probably why I have been selected. I have cudgelled my brains to know what has been my connection with oil during my past somewhat varied career, and I find that in my early days I used to fill up a very rocky motor bicycle with petrol: it was really petrol in those days. Further, I think I have been given at various times certain petroleum substitutes or petroleum products to take internally. Thirdly—and I thought I was alone in this—that some benevolent philanthropist had selected me as the owner of an oil-plot in Arkansas from which for £5 I was to make a fortune beyond the dreams of avarice. Those, I think, are my only connections with the Oil Industry.

The Institution of Petroleum Technologists is a wonderful Institution. The industry is a comparatively new one, as I take it we may really date the petroleum industry from the time when petroleum began to gush forth from the ground in the way we have just heard, and produced only heavy claims for compensation from the surrounding landowners. I believe a former speaker said that was the only result. The Institution, I believe, was founded in 1914. Speaking seriously, the Petroleum Industry is indeed fortunate in having in quite an early stage of its career a scientific organisation like your Institution attached to it. Too often it happens that an industry grows up and develops in entire ignorance of science, and only considers scientific work with respect when it is really on the down grade. Only then it begins to realise that it is necessary, in order that it may stay that decay which is threatening it, to have regard for science. In the Petroleum Industry you are indeed fortunate in the early stages of the industry in the fact that you have at once embraced science, and that you have for your oil business the finest scientific brains that you can obtain. There is no question that the Institution of Petroleum Technologists does a very great work in keeping the producer in touch with the scientific work which is going on all over the world in relation to petroleum, because, whatever else may be said of this age, it is unquestionably the age of oil. The great advances that have been made in the last twenty or thirty years have been in the use of oil for speeding up the world's work. I need not cite the motor-car, the aeroplane, and the thousand other things which would not be possible without oil. There is no question it is oil which has made our present civilisation exactly what it is, and has been accountable for its advance in the last few years.

I understand you have a Standardisation Committee whose work is chiefly to enable all those—at least, this is what I am told—over the whole world who are interested in oil to speak the same language.

Gentlemen, it is my duty and my pleasure to propose the toast of "The Institution of Petroleum Technologists." It has progressed and it is progressing. Among our too many scientific institutions it fills a great want, and it is doing a great work. You have associated with it some of the greatest names among the scientific men of this country. I speak of men like Sir John Cadman, Sir Thomas Holland, Prof. Brame, Mr. Barringer, and others who are doing very great work for the Petroleum Industry not only of this country but of the whole world. I am to couple Mr. Barringer's name with this toast. One of the greatest problems of oil has always been the question of transit. One of the things that made it possible was the early work that was done on tank steamers. Little as I know about oil, I know that. You know the work that Mr. Barringer does for your Institution, and it is

with the greatest pleasure and also with the greatest confidence that I ask you to drink the toast of "The Institution of Petroleum Technologists," coupled with the name of Mr. H. Barringer.

The toast was drunk with musical honours.

The President: Gentlemen,—I must first thank Mr. Garland very heartily for the very effective way in which he has suddenly stepped into the breach in the place of Lord Chelmsford. I think the Institution is to be congratulated that Lord Chelmsford had arranged to propose this toast as the official representative of the greatest oil-burning Navy of the world. It is only due to his Parliamentary duties that he is not present with us to-night. I must also thank you, gentlemen, for the very cordial way in which you have received this toast. Lewis Carroll, before making a speech, was wont to assume a postulate: "Let it be granted that the speech be made on any subject and at any distance from that subject." Now, gentlemen, to-night I have a subject, and I do not propose to wander at any distance from that subject. In the first place, if you will bear with me for a few minutes, I should like to say a few words as to the work of the Institution during the last year. We have elected 130 new members. (Hear, hear.) Our total now approaches 700, which, considering the comparatively limited field from which you have to draw, and the care which we take in the election of our members, I think is a very satisfactory position. Our meetings have been held monthly, and the papers and discussions following on them have maintained the high standard of previous sessions; the attendance has averaged 115. We are represented on some eight to ten different committees at the present time.

There are one or two outstanding features of the session to which I should like to call attention. The first is, as has already been mentioned, the Standardisation Committee, which has completed its labours. The results will shortly be published in a booklet of some 100 pages. The thanks of not only the Institution but of the Industry are due to those gentlemen on the Committee, especially Mr. Alexander Duckham, the Chairman and the co-opted members, for their generous gift of time and experience in compiling this Report. (Applause.) It has entailed an immense amount of labour, correspondence and investigation. It will prove to be of the utmost value, and everyone connected with the Industry should secure a copy. Secondly, we have this session instituted a Student Section, with branches in London and Birmingham, with very encouraging results. Excellent papers have been delivered and good discussions have taken place. The Birmingham University has offered special facilities for practical work. Three full-sized drilling rigs are now in course of erection on the ground, and

the students will have practical knowledge of actual drilling, though I am afraid they will not strike any gushers. Owing to the generosity of one of our friends we have been able to offer special and valuable prizes to those students for proficiency in study. They are all very keen and mean to make it a great success. I will take this opportunity to thank our other friends who so generously support the Institution and add to its efficiency. We are assisting the students in their work, and I am sure that in the future we shall turn out some highly trained men who will be a great asset to the Industry. We are at present instilling the fact that the job comes before the man. We are now occupying our new premises and our house-warming was a most successful function. We are able to accommodate our London students at their meetings in our large hall, and a screen and lantern have been installed for their use. We are joining with the Mining Congress in the great Empire Exhibition this year at Wembley, and during four days from June 3 general lectures will be given by the members of the Institution. Petroleum mining is perhaps a doubtful term. We generally associate mining with digging, and the miner we regard as one who digs. If I called an oil winner a miner who bores I might be misunderstood. (Laughter.) We do hope that during the session at the Exhibition we shall have a good attendance of our members during the lectures. Though one may say that oil mining is one of the youngest sections, it is none the less important, as I suppose no industry has advanced so rapidly as the Oil Industry in recent years. The other day I came across an old Charter granted for mining in the time of James VI. of Scotland, which was rather quaintly worded. They were empowered to dig "in ye earth to ye suburbs of hell in search for ye gold mines." Gentlemen, at times we go rather deep, but generally I do not think we have anything to fear. If we have trouble it is generally with water, but I have always understood that that is rather scarce in the region alluded to. (Laughter.) Petroleum is the life blood of the Empire; as has been mentioned, for our Navy, our Army, our Air Force and commercially we look to oil. I think our medical friends say that they also use our products; whether to our benefit or not I am uncertain. In a way we are one of the custodians of this vital product. We have our geologists who locate the oil, our chemists who tell us how best to treat that oil to produce the products which we require, and our engineers who have been alongside all the time. In petroleum we have a magic carpet. I have heard it argued whether this magic carpet was fitted with reciprocating engines or with turbines, but it is my opinion that it was fitted with a supernatural aero-engine, driven, shall we say, by "A spirit of the East." (Laughter.) I have no doubt that I could weary you

with a good deal more information as to the doings of the Institution, but I will not do so. I will now refer to our Hon. Secretary, Mr. Arthur W. Eastlake. (Applause.) Few members have any idea of the amount of time he devotes to the welfare of the Institution, but I am sure we all appreciate his services. I made an endeavour to-night to induce him to speak, but I understood him to say that he was qualifying for the Silent Service. (Laughter.) We all know what that service is, and I am sure that the thanks of the Institution are due to Mr. Eastlake for his unwearied efforts on their behalf. (Applause.) Then there is Dr. A. E. Dunstan, our Hon. Editor, who is working without cessation. Last year I announced he was to issue six journals instead of four during the year. This year he is busy on the decennial index. He is also proposing to publish a review of the Progress of Naphthology —an annual review. I think the sincere thanks of the Institution are due to him for his continued efforts. (Applause.) Then Mr. A. C. Adams, the Chairman of our Finance Committee, who looks after our funds, is still very active, and it is largely due to his successful guidance that we are in such a sound position as we are at the present time financially. (Hear, hear.) Then there is our energetic Secretary, Commander R. E. Stokes-Rees, R.N. His activities are unabated; during our change of premises he and the staff had a great deal of extra work. As would be expected, the change was completed in record time. The Institution are to be congratulated in having a Secretary and staff who have the welfare of the Institution so closely at heart. (Applause.)

Gentlemen, I think I have said enough to convince you that we are very much alive. As Sir Westcott Abell mentioned a brighter London, I think we are not only making a brighter London but we are making a brighter world. You will remember that Alice said to the Queen: "We must run as fast as we can to remain where we are." Gentlemen, I think we have run a little faster than we can because we have progressed considerably. I must thank you again for the way you have received this toast and also for the classical and melodious way in which you have alluded to me personally.

"OUR GUESTS."

Dr. A. E. Dunstan: Mr. President and Gentlemen,—Before speaking to this toast, I have a short announcement to make. Letters expressing regret at their inability to attend the dinner have been received from, among others, H.R.H. The Prince of Wales, H.R.H. The Duke of York, H.R.H. Prince George, the Rt. Hon. Viscount Cowdray, the Rt. Hon. Vincent Long, the Rt. Hon. Lord Inverforth, Mr. F. E. Powell, Sir Charles Greenway, Bart.,

the Rt. Hon. Lord Bearsted, Sir Robert Waley Cohen, Air Chief Marshal Sir Hugh Trenchard, General Sir Walter Campbell and Sir Oswyn Murray.

I think it will be generally admitted that the toast I have the honour of proposing this evening is, next to that of "The King," the most important on the list, because very obviously the chief purpose of a function of this type is the entertainment of distinguished guests, many of whom know us well and all of whom we hope will know us better. If the presence of a number of eminent men at an Annual Dinner is a criterion of the standing of a learned Society—and I think it must be—then this Institution is indeed fortunate to-night. At this time of the evening brevity is obviously called for, and it would be impossible to detail biographically the important personages we are toasting, but at the risk of making invidious distinctions one should briefly refer to a few of the gentlemen present to-night. We should have been honoured by the presence of Lord Chelmsford, who has always taken much interest in the work of petroleum technologists. In his absence we were certainly delighted by a most brilliant speech from Mr. Garland. I would also mention the Secretary of the Royal Society of Arts. So often have we been his guests in the Hall of that Society that it would have been a real pleasure to us, in our capacity as host, to have had him with us to-night, but he was unfortunately prevented from being present. (Applause.) Mr. James Hamilton is particularly welcome, because we should like to acknowledge the generosity of his Company, the Anglo-American Oil Company, in the interests of the welfare of our Student Section. A very handsome gift, as you know, was offered last year by Mr. Powell in this room, and the students will obtain the benefits of that in the future. Knowing how willing he is to do anything that can be done to further the interests of our Institution, we are very glad to own our indebtedness to Mr. Hamilton. General Brancker, whose name I shall invite you to couple with Sir Geoffrey Salmond of the Air Force, we can almost regard as a customer of ours. The Institution has always maintained close touch with their Departments, and we are most happy to assist in supplies, preparing specifications, investigation, and other services. We were to have the honour of the presence of Dr. Keene, Principal of the Sir John Cass Institute. He is unfortunately away, but Mr. Patchin of that Institution is with us. One of our most important functions is education, and the efforts of Dr. Keene in drawing up schemes of technical education in naphthology are looked on most sympathetically by the Council of the Institution of Petroleum Technologists. Time forbids any further detail, but I would like personally to welcome Sir J. Petavel, of the National Physical Laboratory. Several members of his staff have done yeoman

service in connection with the Standardisation Committee. I think I may mention Mr. Higgins in that connection. It is a very real pleasure to have representatives of the National Physical Laboratory here to-night. I have to associate this toast with the name of Major Rigg. Major Rigg is so well known that it is a work of supererrogation on my part to describe his many functions, and therefore I ask you, gentlemen, to drink the toast of "The Guests," coupled with the name of Major Rigg.

The toast was duly honoured.

Major R. Rigg, O.B.E.: Mr. President and Gentlemen,—I remember some few years ago taking up an interesting little book written in the 'seventies of last century, and in that book various characteristics of the then public men were freely and fully discussed. In it was stated that General Shenck, the then American Ambassador in London, was reputed to be the best five minutes speaker in Congress; whilst Lord Coleridge, then fresh from the triumph of the Tichborne claimant's overthrow, had the reputation of being the best forty days' speaker in the world. Gentlemen, I am going to put your minds at rest now once and for all by assuring you it will be my aim and ambition to-night to follow in the footsteps of the American Ambassador rather than in those of Lord Coleridge.

I am very pleased indeed that this toast was proposed by Dr. Dunstan, for this gives me an opportunity, as one outside your profession altogether, of paying my own tribute to the Journal of the Institution. I am sure your profession owes to him, and I am confident you feel, a debt of gratitude for his having placed his great scientific knowledge and his wonderful literary ability so freely at the service of the profession, coupled with that close application and strenuous perseverance which he displays in carrying out the duties of his office.

While we listened with such great pleasure to-night to the speech of Sir Westcott Abell, I rather think he allowed his historical imagination to run riot, for he practically told us that the oil industry was coeval with the race of man. But, gentlemen, if we come back to the sound and solid bedrock of ascertained historical fact, I venture to say that it would be found during the past quarter of a century there is nothing which stands out in such bold relief among the great industrial developments of this country as the rise of this great oil industry. The Chairman rightly referred to the fact of this great industry being the life blood of the nation. It is vital to the Navy, the Army, and the Air Force and to commerce, and he hinted even to the medical profession itself. Gentlemen, I should like, as one rather closely associated with the

City of London, to pay my own tribute to this great industry, and to stress the important part which petrol to-day plays so far as transport is concerned, and the great services it is rendering in the acceleration of traffic so far as our streets are concerned. Many of us look forward with confident hope to the important place which petrol will play as the great motive power in the not-distant future so far as aerial transport is concerned. As a pure layman it strikes me very forcibly that one of the strongest outward and visible signs of the enormous importance of your industry to-day is the placing of pump stations in various parts of the country where cars and various motor vehicles are enabled to replenish their supply of fuel. Gentlemen, when Mr. Beeby Thompson was speaking he seemed to me to point to one unique feature of this profession. He pointed out that the profession of petroleum technologist trenches on the domain of so many other professions. He referred to chemistry, to geology, to mining, to mechanical and civil engineering, and last but not least to its close and intimate association with finance. When I think of the rise of the Institution of Petroleum Technologists, when I think of those twenty-nine men who in November, 1913, conceived the idea and were men who possessed a faith which would almost remove mountains, when I think of the position which this Institution occupies to-day, I cannot help but say that the founders builded better than they knew. (Applause.) As I listened to Mr. Beeby Thompson I could not help but feel what a splendid service your Institution was rendering as a great co-ordinating and collaborating agency, each man, a specialist in his own particular sphere, being able, through the Institution of Petroleum Technologists, to keep some grasp on the work of the other collateral branches. Your President referred to the wonderful development of the Institution so far as the students were concerned. Gentlemen, I regard this profession as the great new profession of the twentieth century, and you have, as an Institution, a bounden duty towards those young men who are coming forward in the profession. It is a very gratifying fact to feel that that student section has been so well and so loyally supported by your students backed up, as it has been, by the generosity of the Anglo-American Oil Company. (Hear, hear.) I do not lose sight of the fact that the great progressive University of Birmingham has laid down its own special course for petroleum technologists, and the same example has been followed in the case of the Imperial School of Science and Technology at South Kensington. (Applause.) May we not rightly and reasonably ask ourselves to-night the question: Is not this great forward movement due in no small measure to the initiative and to the inception of your own Institution? (Applause.) The great importance and the great objective, I conceive, of this Institution is to raise the

dignity and elevate the status of what is undoubtedly an honourable profession. It is, I conceive, by the efforts of such an Institution as this that you will place your own profession in the days that are to come on the same level as the other great learned professions of our country which are older in date. You are not merely doing that, but you are laying down for your profession the high standard of honour founded on those great moral and intellectual qualities which, after all, are the glory of the professions of this country. You have a great work to do in that, and as a visitor I wish you well in those efforts.

Gentlemen, speaking on behalf of my brother guests to-night, I think I shall echo their sentiments when I say it is our fervent wish that the Institution of Petroleum Technologists may go on from strength to strength, and that in the days which are to come it may stand side by side in an equally high status with the other learned professions of this country. (Applause.)

The Hypochlorite Process

A lecture delivered before the Technologisch Gezelschap, University of Delft, by A. E. DUNSTAN, D.Sc., F.I.C., F.C.S.

ELIMINATION OF SULPHUR FROM PETROLEUM DISTILLATES.

IT has long been established that the objectionable nature of unrefined petroleum products is largely due to compounds of sulphur, present in relatively small proportion. While this statement applies to nearly all petroleum products, it is particularly true of gasoline and kerosene. The offensive odours possessed by most unrefined gasolines are due chiefly to very small proportions of mercaptans, and, in certain oils to a lesser extent, to nitrogen bases and simple naphthenic or thionaphthenic acids. Unrefined gasolines are also usually corrosive to metal, and this is attributed to sulphur derivatives or more probably to dissolve elementary sulphur. Gasoline and kerosene of offensive odour also usually show a positive "Doctor" test, *i.e.*, they react with sodium plumbite solution. In addition to these effects, the use of sulphurous motor spirit, particularly benzol blends, which are apt to have a high percentage of sulphur, results in the formation of acids on combustion, which in some circumstances cause serious corrosion. The discoloration and development of acidity in gasoline and kerosene that have been stored for some time are also frequently attributed to sulphur compounds, although these effects are certainly more pronounced in the case of cracked oils, which have been refined by sulphuric acid. Sulphur as an impurity is probably not so serious in kerosene as in gasoline, although it is known to cause filming of lamp chimneys and charring and uneven burning of the wick. It is also probably partly responsible for discoloration during storage.

The method of refining by dilute hypochlorite solutions described below seems to be applicable for desulphurising and deodorising the gasoline and kerosene distillates from all types of crude. For example, it can be successfully applied to the refining of naphthas from Mexican crudes, which are not at all amenable to the Frasch method. It should be pointed out also that under the conditions as defined below no chlorine is introduced into the oil.

HISTORY OF THE HYPOCHLORITE PROCESS.

Many attempts have been made to use sodium hypochlorite and bleaching powder for refining petroleum, but in most cases the hypochlorite was used either in strongly alkaline solution, so that

little reaction took place, or else in a solution so acidic that chlorination ensued.

That the hypochlorite method of refining petroleum distillates was not developed many years ago is probably due to the fact that the first attempts resulted in the production of chlorine-substituted compounds in the oil. The natural conservatism surrounding a long-established process (the use of sulphuric acid and soda), together with the fact that only in recent years has liquid chlorine become a really cheap, bulk staple of the chemical industries, have also been factors in retarding the development and adoption of the new method. Special methods for the cheap and safe transportation of liquid chlorine have also been developed, *e.g.*, specially designed tank cars, and consequently liquid chlorine has rapidly been replacing bleaching powder among consumers of large quantities of this reagent.

Previous work on refining by hypochlorite may be concisely summarised :—

A. Brin and L. O. Brin (Brit. Pat. 10,968 (1896)) treat oils with oxygen, ozone or chlorine gases in order to decolorise and desulphurise them.

H. A. Frasch (U.S. Pat. 525,811 (1894)) agitates oils with a suspension of chloride of lime or bleaching powder. This treatment is followed by one with sulphuric acid and then finally with a solution of sodium plumbite. The latter reagent, it is claimed, is used only to remove chlorine compounds.

Gray (Brit. Pat. 5,132 (1889)) mixes the oil with a solution of chlorinated potassium hydroxide or sodium hydroxide. The latter is prepared by adding caustic alkali to a suspension of chloride of lime.

Armstrong (U.S. Pat. 837,655 (1906)) refines petroleum distillates by shaking with a reagent prepared by dissolving chloride of lime in water, separating the clear solution and then adding to it an alkaline carbonate.

H. Frasch (U.S. Pat. 622,799 (1899)) refines oils with substances containing free chlorine and then removes any remaining chlorinated derivatives by a final treatment with a basic metallic salt.

Colin and Amend (U.S. Pat. 723,368 (1903)) desulphurise petroleum distillates by means of a hypochlorite in alkaline solution and in conjunction with catalysts. The reaction, which they claim is principally one of oxidation, is carried on in the presence of an oxygen carrier. The excess chlorine is removed by the use of some salt of a heavy metal which is capable of existing in two or more states of oxidation, such as manganese or iron. They base their principle of oxidation upon the fact that when chlorine gas is passed into a solution of sodium hydroxide containing a so-called oxygen carrier, such as a compound of manganese, cobalt, nickel,

copper or iron, the hypochlorite is decomposed into the corresponding chloride and oxygen without the production of free chlorine, and chlorination is thus inhibited. The method of procedure is as follows : The distillate is agitated with a solution of sodium or calcium hypochlorite to which has been added a very small amount of manganous nitrate, or manganese dioxide. The hydroxide thus formed gives up its oxygen to the sulphur compounds existing in the hydrocarbon mixture and is then again reoxidised by the hypochlorite. The oxidising powder of the manganese dioxide is claimed to be very much increased by virtue of its fine state of division. Any excess of hypochlorous acid or its derivatives is removed by some reducing agent. Very good results are said to be obtained by the application of this method.

Young and Peake (Chem. & Met. 1922, (972) have described the use of bleaching powder for sweetening and desulphurising gasoline on a large scale at the Mid-West Refining Company in Natrona County, Wyoming. This method has been in use, as the authors state, since 1921 for refining a natural gasoline blend on a commercial scale and very good results have been obtained.

Regarding the use of hypochlorite solution alone in the refining of cracked distillates, no very conclusive work has yet been done. The problem of oxidising compounds present in cracked distillates is very different from that met with in connexion with straight run distillates. However, it may be mentioned that cracked distillates vary considerably in composition, depending upon the source of the raw oil charging stock and that the composition of some of these distillates is, indeed, very complex. By combining the hypochlorite treatment with some form of the sulphuric acid treatment, good products may be obtained and a great saving of sulphuric acid may be effected.

In 1918, however, the author and his colleagues discovered that the key to the successful application of hypochlorite was the quantity of free alkali present—a quantity which could be allowed to vary only between narrow limits. From that time onwards the hypochlorite treatment evolved very rapidly and soon progressed beyond the laboratory scale. Minor difficulties which arose when the trials were made on a larger scale were eventually surmounted and the desulphurisation of benzine and kerosene by means of sodium hypochlorite solution has become a commercial proposition of considerable magnitude. Several hundred million gallons of distillates have been successfully treated in the last three years, and a large number of refineries are making use of the process.

Action of Hypochlorite on Sulphur Compounds.

Sodium hypochlorite is essentially an oxidising agent. Its function is to oxidise the sulphur compounds in the oil to other

compounds, which are odourless and easily removed by virtue of their solubility in water and alkali. Our knowledge of the nature of these sulphur bodies is, even at the present time, by no means extensive, but there are certain types of compounds which are known to be present in petroleum distillates and may conveniently be used to demonstrate the action of hypochlorite :—

Mercaptans.—These are organic sulphur compounds which contain the SH group. They possess an extremely unpleasant odour and are present to a small extent in many sulphurous oils. They are oxidised by hypochlorite to sulphonic acids, which are soluble in both water and caustic soda solution, so that those which do not come away with the spent hypochlorite are extracted by a subsequent soda wash, as described later.

Alkyl Sulphides.—These are oxidised to sulphones, which are soluble in alkali, and are removed in the spent hypochlorite and the subsequent alkali wash.

Other Sulphur Bodies.—These are unknown in structure and are oxidised to unknown compounds. In the case of those of lower molecular weight, however, these products are found to be soluble in either water or caustic soda, but the higher-boiling compounds, which are present in the kerosene fraction, are not completely removed in this way. The presence of a methoxy mercaptan has been indicated and work is still going on in this direction.

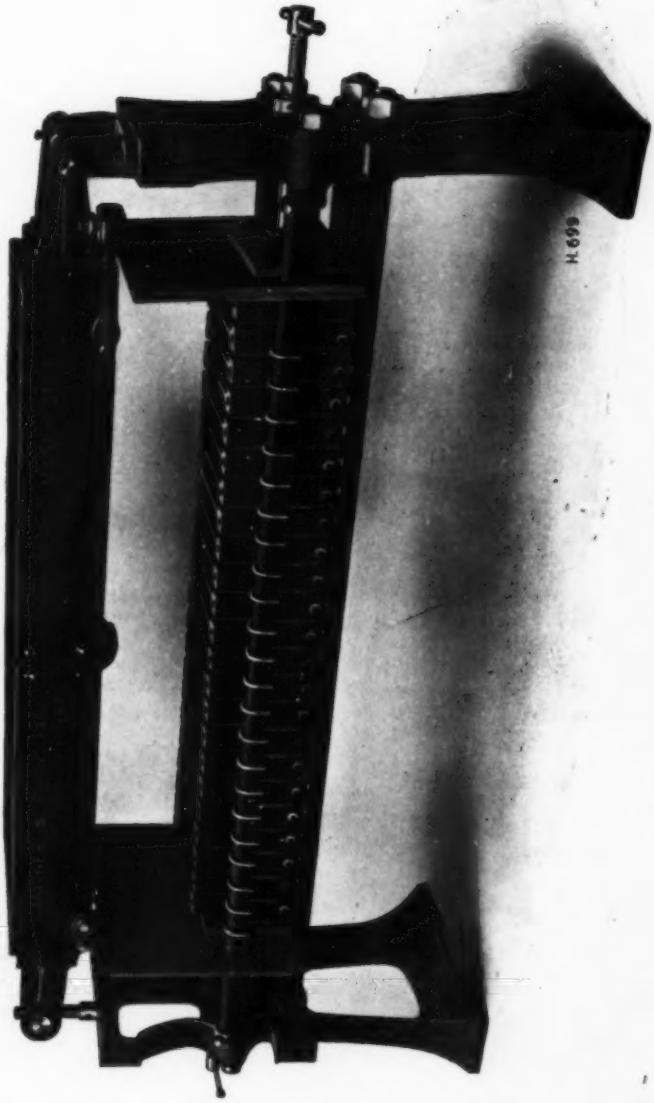
Treatment with hypochlorite is thus seen to render soluble in water or in alkali, sulphur-containing bodies, which otherwise cannot be readily separated from the oil.

Mather and Platt's Patent Electrolyser—Vertical Flow Type.

This electrolyser consists of cells formed by suitable insulating distance frames between plates of graphite carbon, supported on vulcanite covered steel bars, and carried by cast-iron end frames. End pressure screws are provided for adjusting purposes.

The two end carbon plates form the terminal electrodes, and are connected to the positive and negative poles of the dynamo or to the source of electric supply. The carbons are shaped at the top to receive the brine liquor falling in drops through the perforated bottom of a top cast-iron tank, which is lined with vulcanite. Each cell is fitted with a syphon outlet tube, which regulates the flow and ensures that each cell is full. The distances from the top tank to the cells, and from the syphon tube to the collecting trough underneath, are such as to prevent current leakage.

No part of the apparatus, with the exception of the carbons, can be acted on either chemically by the solution or electrolytically by



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ELECTROLYSER.

the electric current. These carbon plates are of ample thickness, and after wear are trued up and again placed in the apparatus. A pump delivers the brine solution (prepared by dissolving common salt, as free from impurities as can conveniently be obtained, in pure water) into the top tank, whence it gravitates into the electrolyser cells underneath. From the syphon outlet to each cell the brine falls into a concrete collecting trough, and is directed into the circulating tank, from which the liquor is again drawn by the pump. When the brine flows from the syphon pipes the current is switched on, and the direction of flow of the current should be reversed at stated intervals by means of the throw-over switch. When, by the passage of the current, the brine has been brought to the desired degree of chlorine strength it is pumped into the storage tank. This bleaching solution may be stored at the prepared strength for two or three days (although it is better to use it the same day as or the day after it is prepared), and reduced by the addition of water according to the requirements of the particular refining operations.

As may be understood, the most economical brine solution to employ is determined by the relative cost of salt and of electric power ; in the average case, the 12½ per cent. solution is the most economical, and this is the strength assumed in the following data. The solution is circulated by a pump through the electrolyser at approximately 18 gallons or 80 litre per minute. The circulation of the brine and the passage of the current are continued till the brine contains from 11 to 12 grammes of available chlorine per litre. During this period the temperature, as observed in the top tank, should not be allowed to rise above 32° C. The cooling pipes in the circulating tank provide means of controlling this.

The standard electrolyser with 22 cells is designed for 100–110 volts, and the current required for the full output is 225–250 amperes. When working with the 12½ per cent. brine solution and with a current of from 225–250 amperes, a standard electrolyser will produce about 9 lbs. of available chlorine per hour if the electrolyte be worked up to a strength of from 10 to 11 grammes available chlorine per litre. To state the output otherwise : to produce 1 lb. of active chlorine, three kilowatt-hours of electricity and 12 lbs. of salt are required.

The electrolyte thus produced must contain a certain amount of free alkali to prevent deterioration in storage, give ease of application and prevent decomposition by the action of light. For the last reason, the windows of the electrolyser house are painted red.

The manufacture of hypochlorite is not limited to the electrolytic process which, however, is very economical when salt and current charges are low. In fact the pre-war prices for salt and electrical

energy made this method by far the most efficient means of obtaining the reagent. Post-war prices, coupled with the ultimate wear and tear of carbons electrodes, may turn the economic balance in favour of the chlorine-soda process.

Chlorine-Soda Process.

When it is possible to buy liquid chlorine in cylinders or tank-waggons at a reasonable price, a very satisfactory method of making hypochlorite is to allow caustic soda to absorb chlorine until the required strength is reached. A 10 per cent. solution of caustic soda is put into a tank provided with stirring gear and chlorine is then bubbled in through a perforated pipe. While the chlorine is being absorbed by the soda, samples are constantly tested until the strength reaches about 2·0 N available chlorine. During the absorption, the liquid should be thoroughly agitated by means of the circulating pump in order to avoid local concentration of the chlorine.

The heat of reaction is not considerable, but it is of advantage to provide cooling coils, since, if the temperature becomes too high, decomposition of hypochlorite and formation of chlorate occurs.

The strong hypochlorite solution is perfectly stable and is stored until required, when it is diluted to about 0·3 N, which is the most convenient strength for treating the oil. The dilute solution should contain between one half and one gram of free caustic soda per litre, so that three to six grams may be left in the 2 N solution, which is diluted to 6–7 times its volume.

The method of testing the normality (available chlorine content) of the solution is as follows :—

A sample of the hypochlorite solution is taken and, after suitable dilution, potassium iodide and a known amount of hydrochloric acid are added and the iodine liberated (being equivalent to the oxygen contained in the hypochlorite) is titrated with neutral sodium thiosulphate.

Free Sodium Hydroxide.

To the colourless solution resulting from the above titration one drop of methyl orange is added, and the excess of hydrochloric acid is titrated with N/10 sodium carbonate solution, so as to obtain the concentration of free sodium hydroxide.

As a works test of the alkalinity of the concentrated solution,

to 5 c.c. are added 20 c.c. of neutralised "20 volume" hydrogen proxide. This destroys the hypochlorite and the remaining alkali is titrated in the usual manner.

Treatment.

The sulphur derivatives in petroleum distillates are oxidised by agitating the oil with dilute hypochlorite solutions. A concentration of 12 g. of available chlorine per litre (0·3 N) is employed and agitation is accomplished by circulating the aqueous solution through centrifugal pumps discharging below the surface of the oil. The agitators are of mild steel and are not lead lined, experience having shown that corrosion of the agitators does not proceed beyond a slight filming of the metal.

The usual treatment is detailed below. The starting-out material is "Once Run Distillate" (O.R.D.) or naphtha, and contains the benzine and kerosene.

(1) Initial soda wash.
(2) Water wash.
(3) First hypochlorite wash.
(4) Second hypochlorite wash.
(5) Final soda wash.
(6) Water wash.
(7) Redistillation over soda to give a benzine distillate and a kerosene residue, which is filtered through bauxite.

The alkali washes constitute an essential part of the process, each wash removing a portion of the sulphur-bodies, as shown below.

Initial Soda Wash.

The freshly distilled O.R.D. contains hydrogen sulphide and sulphur dioxide in solution. These interact to form sulphur, but the action is very slow in the absence of water and is, in all probability, not complete for two or three days. The elemental sulphur thus formed can only be removed by redistillation, so it is desirable to treat O.R.D. while it is quite fresh. In this case a good deal of the sulphuretted hydrogen and sulphur dioxide is still present as such and may be removed by the initial soda wash, which converts these bodies into sodium sulphide and sodium sulphite respectively. Certain organic sulphur compounds of unknown constitution are also dissolved by the soda, and they appear to enter into a balanced

reaction with the caustic soda in such a way that they can never be removed in entirety, although a number of washes will each remove a proportion. It is not, however, economical to give more than one soda wash before application of the hypochlorite. There is evidence that soda removes more sulphur from a fresh O.R.D. than from a stale one.

The compounds just referred to are equally well removed by hypochlorite, but this is a more expensive substance than the caustic soda which is recoverable, so that it is an advantage to reduce the amount of hypochlorite required by giving an initial soda wash. Recent work shows that a preliminary milk of lime wash is quite satisfactory, followed by calcium hypochlorite.

The oil and the caustic soda (3 per cent. by vol. of a 10 per cent. solution) are run into a washer and thoroughly agitated by means of a circulating pump for about half an hour. The contents of the washer are then allowed to settle for about 10 minutes, after which the soda is run off and the oil washed with water to remove traces of alkali which would reduce the activity of the hypochlorite. The used caustic soda from this preliminary wash is by no means exhausted and details of its recovery will be found described later. The distillate is then ready for the first hypochlorite wash.

First Hypochlorite Wash.

After the initial soda wash has removed such acidic bodies and sulphur derivatives as are amenable to the treatment the oil is agitated with 20 per cent. by volume of 0·3 N hypochlorite.

As mentioned above, it has been found that the most suitable strength of the hypochlorite solution is 0·3 normal and it should not, in any case, be below 0·2 normal. The quantity of free alkali present must lie between the limits of 0·5 gms. and 1·0 gms. of caustic soda per litre. A lesser amount is insufficient to prevent decomposition; a greater amount slows down the reaction to such an extent that the time required for the treatment is inconveniently long.

The oil and hypochlorite are thoroughly agitated together by means of an external circulating pump for a period of ½ hour, after which the mixture is allowed to settle for 15 minutes before the spent hypochlorite is run away to waste or re-electrolysed, as the case may be.

The hypochlorite should be completely exhausted during this wash, *i.e.*, the normality should fall to zero.

Second Hypochlorite Wash.

This is similar in quantity to the first wash, but it has to deal with the less easily oxidisable bodies which have been left untouched by the first wash. The action is, therefore, much slower and agitation must continue for an hour or longer. At the end of the agitation the hypochlorite solution is by no means exhausted, indeed, in some cases its normality has been reduced only from 0·3 to 0·2.

This partially used hypochlorite cannot be satisfactorily re-electrolysed to full strength on account of the organic matter it contains, and hitherto it has largely gone to waste.

The total amount of chlorine absorbed by the oil during both washes should be about 3·5 gms. per litre. This is equivalent to 3½ lbs. per 100 gallons of oil, *i.e.*, a chlorine cost of 10 pence per ton of oil. (Chlorine at £9 per ton.)

However, the two washes contain a chlorine equivalent of approximately 4·5 gms. per litre of oil, and as an equivalent of only 3·5 gms. is used up in the oxidation, exhaustion of the second wash was very serious. Recent research, as indicated later, has shown how this loss may be entirely obviated, and also that the time of treatment can be very materially shortened.

Final Soda Wash.

The chief function of the final soda wash is to take out acidic sulphur—and, perhaps, chlorine—containing bodies which have been oxidised, but not removed by the hypochlorite.

This wash conducted similarly to the initial soda wash. It is found to be quite efficient to use the effluent from this wash again as the initial soda wash for the next batch. As in the case of the initial soda wash, it is followed by a water wash.

The final soda wash is an important part of the process, inasmuch as it removes a by no means inconsiderable proportion of the total sulphur. In this connection it is interesting to note the various proportions of the total sulphur removed by various washes.

Percentage of Sulphur Removed at Each Stage.

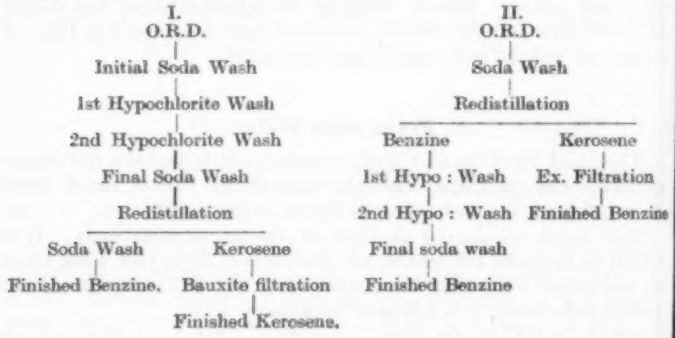
The following data show how nearly complete is the elimination of sulphur. These figures show how considerably the effect of the initial soda treatment varies with the age of the oil. During the redistillation (in the presence of steam) some of the sulphur bodies are decomposed and partly removed in the water and by the small

quantity of caustic soda present in the still. The finished benzine is a perfectly sweet neutral spirit of less than 0·011 per cent. sulphur.

	Exp. 1.	Exp. 2.	Exp. 3.
Initial Soda Wash—			
% Sulphur removed	13·7	4·8	19
1st Hypochlorite Wash—			
% Sulphur removed	22·4	27·7	24
2nd Hypochlorite Wash—			
% Sulphur removed	19·0	21·7	14
Final Soda Wash—			
% Sulphur Removed	14·6	27·8	9
Redistillation and Soda wash of benzine distillate—			
% Sulphur removed	23·3	7·2	25
Total % Sulphur removed ..	93·0	89·2	91

Variations in the Treatment of Distillates.

The hypochlorite treatment may be applied to the Once Run Distillate or it may be held over until after the redistillation of soda washed O.R.D. and applied to the benzine only. The two methods may be tabulated as follows :—



There is little to choose between these two methods, and the procedure is decided chiefly by cost and convenience.

By treating the O.R.D. a superfine finished benzine is obtained and the kerosene residue from the redistillation can be satisfactorily refined by means of 2 lb. of bauxite per gallon.

By treating the benzine after redistillation, the finished product is good, but the kerosene needs 4 lbs. of bauxite per gallon, as it has not been subjected to the refining action of the hypochlorite. Moreover it is slightly more liable to reversion of colour. On the other hand a certain amount of hypochlorite is saved, so that the procedure depends upon whether it is cheaper or more convenient to use less hypochlorite and more bauxite or vice versa.

A typical treatment is shown hereunder :—

Once run distillate { Sp. Gr. .. .. 0·750 ; Sulphur .. .. 0·15% ; Colour .. .. "Prime White."

Initial Soda Wash

1st Hypochlorite Wash

2nd Hypochlorite Wash

Final Soda Wash

Redistillation

Finished benzine (No. 1 Spirit) { Sp. Gr. .. 0·729 ; Sulphur .. 0·01% ; Chlorine .. 0·01%

Kerosene Residue

Filtration through Bauxite

Finished Kerosene. { Sulphur .. 0·06 to 0·10% ; Chlorine .. 0·01% ; Colour .. "Water White" ; Sp. Gr. .. 0·790

When gasoline only is to be treated, the filtering operation may, of course, be dispensed with. The purification is so effective that with gasoline from Persian Oil, containing originally the percentage of sulphur indicated above, the regular commercial output passes the following tests :—

(1) 100 c.c. gasoline plus 1 c.c. $KMnO_4$ (0·1 N. soln.) plus 2 c.c. 10 per cent. sulphuric acid, and vigorously shaken retains the permanganate colour for 10 minutes and usually longer.
(2) When a sample of the gasoline is treated with sodium and alcohol and, after the reaction is over, slightly acidified and tested with lead acetate, no film of lead sulphide can be detected.
(3) The copper dish test is entirely negative.
(4) The Doctor test is negative.

Reactivity and Stability of Hypochlorite Solutions.

The reactivity of hypochlorite in oxidising sulphur-bodies in the oil, and its stability towards actinic light, both depend on the "free alkalinity" of the solution. Free alkali exerts considerable stabilising influence when present in very small quantity, and, in refining, the amounts of free alkali in the 0·3 N. solution has been rigidly specified as 0·5 to 1·0 gms. caustic soda per litre (*i.e.*, 0·025 to 0·0125 N.). Such a solution is quite stable enough to

handle without loss. With the maximum concentration of alkali allowed (1·0 gm./litre), or with a greater quantity the rate of oxidation becomes very slow. A typical experiment s shown herewith :—

O.R.D. given a 30% wash of Sodium Hypochlorite of 0·336 N. containing 1 gm. free NaOH/litre.

Time in minutes.		Normality of NaOCl.
0	..	·336
10	..	·244
20	..	·214
30	..	·198
45	..	·176
60	..	·168

A solution containing less free alkali than the minimum specified has a rapid reaction, but has two great disadvantages. Firstly, it is liable to decompose spontaneously and, secondly, the manufacture of hypochlorite containing so little stabilising alkali involves a control too delicate for application on a works scale, since a small excess of chlorine will lead to the decomposition of the whole batch.

The degree of dilution of the hypochlorite also has a marked effect on its stability, though this is connected with an alteration in the alkalinity of the solution. Thus, the concentrated solution as made on the works scale, of 2·5 N. and containing 6 gms. free caustic soda per litre, is quite stable and can be kept for weeks with very little decomposition. It also reacts extremely slowly with the oil. When diluted eight times the resulting dilute solution is much more reactive. The following figures illustrate this :—

O.R.D. treated with Calcium Hypochlorite. Equivalent quantities were used in each case, but the degree of dilution was different. The original solution was of 0·672 N. containing 0·5 gms. calcium hydroxide per litre.

Normality of Calcium Hypochlorite.		Amount of Calcium hypochlorite exhausted in 30 mins.
0·672	..	36%
0·448	..	42%
0·336	..	49%
0·268	..	51%

As stated previously a 0·3 N. solution has been found the most suitable concentration for use.

The question of alkalinity has an important bearing on the degree of exhaustion of the second hypochlorite wash, which, as previously mentioned, is only very slowly used up. Experiments have demonstrated clearly that it is possible to remove the stabilising alkali at some convenient point in the process—when the action has become very slow. The addition of mineral acid has obvious serious disadvantages which prohibit its use. It was found that some salts of iron, manganese, zinc, magnesium, etc., were capable of accelerating the action since they caused the

precipitation of insoluble metallic hydroxides, resulting in a reduction in the total alkalinity of the solution. This procedure has, however, the drawback of producing flocculent precipitates, which may lead to the formation of emulsions. The best way of destabilising is by the use of carbon dioxide added to the solution in very small quantity. By its use the process can be considerably shortened and there need be no loss of hypochlorite whatever.

Re-Electrolysis.

The spent sodium hypochlorite consists mainly of an aqueous solution of common salt. It is, therefore, possible to reactivate it by simply passing it through the electrolytic plant again. Theoretically this could be done indefinitely, but in practice it is not found economical to do so. The reasons for this are that the current consumption required for re-electrolysis is high and that a steadily increasing quantity of caustic soda is formed which decreases the activity of the hypochlorite and inhibits its use without destabilisation. It is, therefore, found to be cheaper to use fresh brine rather than regenerate spent hypochlorite.

Soda Recovery.

The amount of caustic soda used in the hypochlorite process would be a consideration were it not recoverable. The final soda wash is 3 to 5 per cent. by volume of 10 per cent. solution and the initial soda wash is the same. By using the final soda of one batch as the initial soda for the next batch a substantial economy is effected, but still greater economy may be achieved by a simple method of recovery. This is based upon the fact that the organic sulphur compounds extracted by the soda during the initial wash are comparatively volatile, so that all that is necessary is to heat the spent soda and drive off the sulphur derivatives.

The spent soda is placed in a boiler, boiled until about 10 per cent. of its bulk has distilled off and it is then ready for use again. The gases given off are led round and burned in the flues and the hot recovered soda used to preheat incoming cold soda.

The recovered soda still retains some of the unpleasant odour which is so characteristic of the sulphur compounds, and cannot, therefore, be used for the final alkali wash.

Uses of Calcium Hydroxide instead of Caustic Soda.

Attempts have been made to reduce the cost of the alkali washes by substituting lime for soda. The saving in expense would be

considerable, but there are one or two difficulties which must first be solved. The chief drawback to the adoption of lime is the small solubility which necessitates its use in suspension instead of solution. The equivalent amount of lime in true solution would amount to about five times the volume of the O.R.D. to be treated, and such a state of affairs would reduce the washer capacity and, therefore, the throughput by an enormous amount. On the other hand lime in suspension, though efficient, has a tendency to form emulsions. Experimental work has demonstrated the feasibility of the process.

Calcium Hypochlorite.

The substitution of calcium hypochlorite for the sodium salt has been proved a practical proposition. A substantial reduction in working costs may be obtained by this method, since the solution is made from chlorine and slaked lime instead of the more expensive caustic soda.

In the case of equally concentrated solutions of sodium and calcium hypochlorites, the limiting quantity of lime allowable in order to obtain the requisite activity of the solution is less than the equivalent amount of soda in the case of sodium hypochlorite.

Calcium hypochlorite may be made by passing chlorine into a thoroughly agitated suspension of lime in water, until an approximately clear solution is obtained. This is a solution of calcium hypochlorite saturated with lime and its strength may be 2·3–2·5 N. It is diluted eight times before use, so as to bring it to ·3 N. as is customary with sodium hypochlorite. This solution is as reactive as the equivalent sodium solution and needs about the same time of agitation; its efficiency also is the same and the resulting products are identical with those obtained by the use of this sodium derivative.

Calcium hypochlorite may also be manufactured from bleaching powder by extraction with water. This method, however, is not so satisfactory, as it is impossible to make so strong a solution without a great deal of waste due to the large amount of liquid carried away by the excessive sludge. The maximum convenient strength obtainable in hot climates is about 1·0–1·5 N., and this solution is saturated with lime so that when diluted to 0·3 N. for use it is less reactive than is desirable. This difficulty is aggravated by the fact that the settling out of the free lime in suspension takes far longer than can be allowed, so that the sluggishness of the reaction is intensified by the presence of suspended lime.

Destabilisation of the hypochlorite is, therefore, most desirable. Calcium hypochlorite, however, when made from chlorine and lime, is free from these disadvantages.

Advantages of the Hypochlorite Process.

The advantages of the hypochlorite process as compared with the use of sulphuric acid may be summarised as follows :—

(1) The cost of refining is lower. The introduction of lime instead of soda and of calcium hypochlorite instead of sodium hypochlorite will bring about still further reductions in cost.

(2) There is less loss on refining so that the total saving is materially greater.

(3) No acid sludge is formed and no acid recovery plant is required.

(4) The treatment can be carried out in ordinary steel vessels, since corrosion of washers, piping, etc., is much less than is the case when acid is employed. Lead lined apparatus is not required.

(5) The sum total of operations is easier to carry out than the acid-refining process with the sludge disposal, etc., incident to the latter.

(6) The process is applicable to the light distillation from all types of crude petroleum which contain sulphur.

(7) There is no tendency for the loss of the valuable aromatic hydrocarbons through conversion into sulphonic acids, nor is there the risk of forming oil-soluble alkyl sulphates which will subsequently decompose into sulphuric acid and corrode storage tanks.

Petroleum Ash.

By W. H. Thomas, A.R.S.M.

The following short account of the ash from petroleum, while in itself only an introduction to the subject, will possibly indicate a line of research in petroleum chemistry which will be of value to the naphthologist in general.

The mineral content of petroleum has hitherto been largely overlooked, to such a degree, in fact, that one rarely, if ever, finds a complete analysis of the ash quoted, although the percentage of the ash is invariably determined in analyses of crude oils.

The percentage of ash appears to bear no definite relationship to the type of oil under consideration. For instance, it would be expected that a bitumen would have a high ash content, and as a rule this is found to be the case. (Lobsann bitumen contains 5·4 per cent. ash, and Egyptian asphalt 11 per cent. ash.) On the other hand, Persian crude oil (a mixed base oil) contains less than 0·01 per cent. ash, while oil from the Hardstoft Well, in Derbyshire, although less asphaltic in character, contains as much as 0·05 per cent.

The following analyses, both partial and complete, have been collected from existing literature dealing with the chemistry of oils and from original analyses. Among the works from which these analyses have been abstracted are :—(1) Engler's "Das Erdol," (2) Clarke "Data of Geochemistry," (3) Imperial Mineral Resources Bureau Bulletins, (4) Journals of the Institution of Petroleum Technologists.

Oils.	Ash. %	Constituents of Ash.
Persian (obtained as flue dust from combustion of fuel oil)	0·01	Fe_2O_3 & Al_2O_3—26·96% SiO_2— 2·24% CaO — 2·31% P_2O_5—5·53% MgO — 1·18% SO_3—35·29% V_2O_5 — 5·03% MnO— 4·39% NiO — 2·70% Moisture 14·31%
Hardstoft	0·05	Fe_2O_3 & Al_2O_3—62·85% SiO_2 — 13·40% CaO —12·78% P_2O — 2·34% MgO — 5·62% As — trace
Pennsylvanian		No Ni, but Vd content high.
Mexican (III.)	0·72	Si, Vd, N, Sn, Pb, Co, Mg, Fe, Al, Ti, Na, and Au.
Baku (I.)	0·09	Fe_2O_3, CaO, Al_2O_3, CuO and traces of Ag.
Baku (I.)	0·11	CaO — 5·48%, Fe_2O_3 — 76·71%, insoluble matter — 16·07%
Egyptian (I.)	0·12	CaO, Fe_2O_3, S and traces of Ni and Vd.
Canadian (I.)	—	CaO, MgO, Fe_2O_3, Al_2O_3 and traces of Au and Ag.

Oils.	Ash. %	Constituents of Ash.
Ohio (I.)	0·11	.. Equal parts of CaO, MgO, Fe_2O_3, Al_2O_3 and traces of Au, Ag, Cu.
Patagonian (I.) ..	0·20	.. Cu, N, P (potassium nitrate identified).
Japanese (I.)	0·55 to 0·16	.. CaO, SiO_2—trace of Fe_2O_3.
Chidersyndo (I.) ..	0·09	.. Al, Cu, Pb and traces of Ag and S.

Asphalts.	Ash. %	Constituents of Ash.
Lobsann Bitumen (I.) ..	5·4	.. 17% Fe and traces of Mn. 13% SiO_2 and also CaO and $CaSO_4$ with compounds of Si and S.
Patronite (IV.)	—	.. Very high % of Vd.
Andes (VII.)	—	.. Vd = 43% of ash.
Peru (IV.)	—	.. "Vanadiferous asphalt."
Nevada (VI.)	—	.. Vd = 30% of ash.
Manjak (Trinidad) (VI.) ..	—	.. Vd = 0·52% of ash.
Asphaltite (Utah) (IV.) ..	—	.. Uranium 1·13 to 2·88%, Vanadium 0·25–1·17%.
Grahamite (Oaklahoma) (IV.)		.. Vd = 12·2% of ash.
Shales, Coals and Lignites.		
Scotch Shale (V.)	—	.. Vd = 0·12% of ash.
Joadja Creek Shale (V.) ..	—	.. Vd = 0·01% of ash.
Lignite (Travancore) (V.)	—	.. Vd = 2·0%.
Lignite (San Rafael) (VI.)	0·63	.. Vd = 38·22% of ash. Also Si and SO_3.
Coal (San Rafael) (VI.) ..	—	.. Vd = 38·5% of ash.
Coal (Peru) (VI.)	—	.. Vd = 38·0% of ash.

From a consideration of the above analyses it will be seen that very many elements occur in the ash from petroleum. All the elements quoted in the analyses are widely distributed throughout the sedimentary rocks of the world and, broadly speaking, the major constituents of the ash also occur in abundance in the earth's crust. It is interesting to consider the origin of the various elements or compounds which, at some time or other, the oil must have either taken into solution or into some form of colloidal suspension.

Iron occurs in great abundance in both sedimentary and igneous rocks as native iron, magnetite, Fe_3O_4; Haematite, Fe_2O_3; limonite, $2Fe_2O_3 3H_2O$; gothite, $Fe_2O_3H_2O$; fargite, $2Fe_2O_3 H_2O$; pyrites, FeS_2; marcasite, FeS_2; magnetic pyrites Fe_nS_n+1 (Ni present); chalybite, $FeCO_3$; copperas, $FeSO_4$, $7H_2O$; vivianite, $Fe_3P_2O_8 8H_2O$; silicates of iron and calcium; titaniferous iron ore, etc.

Much of the iron which occurs in Hardstoft oil can be filtered off through cotton wool, and it is possible that the remainder exists in a colloidal state and has been derived from the amorphous variety of iron oxide—limonite. Some of the iron oxide in suspension has possibly been derived from the steel containers, etc., in which the oil has been stored or distilled.

Silicon is one of the major constituents of the earth's crust and exists as silicates of most metals. Felspars, felspathoids, micas,

pyroxenes, amphiboles and other more complex silicates can be found in any type of igneous and sedimentary rocks. This abundance of silicon probably accounts for the prevalence of silica in certain types of petroleum ash. It is difficult to decide, however, in what form the silicon exists in petroleum. It has been suggested that it occurs as very finely divided particles of aluminium silicate (or clay) which are in a state of suspension closely resembling a colloidal solution. It can be assumed, therefore, that these particles were occluded by small globules of oil when the original organic matter was being transformed into petroleum under deltaic conditions. By this means is postulated a probable origin of petroleum whose ash contains a high percentage of silica.

Quite different, however, was the probable origin of petroleums whose ash contains considerable quantities of lime and magnesia. These two constituents indicate an origin where marine conditions predominated. The original material in this case would be minute marine organisms surrounded in some cases by a thin shell of calcite, and whose remains were entombed by succeeding layers of marine detritus.

Where the silica percentage equals approximately the percentages of lime and magnesia together, a "dual origin" of petroleum may be postulated. That is to say, the oil was formed under marine conditions, but sufficiently near the land for the terrestrial organic remains to be deposited in the same locality. It is interesting to note here that in the two ashes, which have received full investigation, the phosphate radical is by no means the least important constituent.

Much has been written of late on the presence of vanadium and nickel in the ash from certain mineral oils. We find that vanadium occurs in considerable quantities in the ash obtained from certain asphalts, noteworthy among which are the vanadiferous bitumens of Peru. An account of these appeared in the *Petroleum Times* of September 22nd, 1923, but no suggestions as to the origin of the vanadium were put forward.

Both nickel and vanadium are widely disseminated throughout the earth's crust, but there appears to be no relationship between commercial deposits of these metals and those of petroleum. It will be interesting, therefore, to consider the biochemical concentration of these metals and the means by which they can become absorbed in petroleum. It is known that certain organisms, both animal and vegetable, secrete metallic salts during life. These salts are not taken up indiscriminately, but the organisms appear to select those which are necessary for their growth and stimulation.

Nickel amongst other metals has been detected in the ash obtained from seaweed (VIII.). In culture experiments nickel has

been shown to be poisonous to plants except in very dilute solutions. Nickel has been detected in a very fertile soil at Pantchero, near Belgrade, which seems to indicate that very minute quantities are actually beneficial to plants. With regard to vanadium, it has been shown that certain plants use vanadium as a substitute for phosphorus (IX.). It also appears to be absorbed by holothurians and ascidians as a substitute for copper and phosphorus in their blood.

In addition, it is interesting to note that crustaceans are rich in zinc and that copper and zinc are found in the blood of molluscs. Certain protozoans segregate barium sulphate and some radiolaria form their skeletons in part from strontium sulphate.

Ramsay's communication (II.) to the Society of Chemical Industry with regard to the presence of nickel in petroleum ash is very germane to this discussion. He states that nearly every type of petroleum contains nickel in varying proportions, and he has put forward the suggestion that the nickel has acted as a catalyst in the hydrogenation of the original material in the formation of petroleum. Obviously it cannot be stated specifically whether the nickel occurs in the metallic state or not. Nickel is never found in the earth's crust in the metallic state, but always in combination with some other element such as sulphur or arsenic. It is difficult to understand, therefore, how the hydrogenation can take place, when it is realised that in the catalytic action and hydrogenation, nickel in the metallic state is essential and moreover in a specially active, finely divided condition. Apart from this, the elements with which nickel is usually found in combination would effectively inhibit catalysis by reason of their "poisoning" action.

A consideration of the solid residue left on evaporating oil-well waters would doubtless throw some further light on the question of petroleum ash and also on the origin of petroleum. Waters obtained from producing wells in Persia are in the main more or less saturated solutions of NaCl, $CaSO_4$ and $MgSO_4$. In addition, however, traces of silica are invariably present, together with amounts of Fe_2O_3 and Al_2O_3 varying from 10—70 parts per 100,000 of water. Ni Vd and Mn, however, have not been detected, which points to the fact that the oil did not originate in the strata in which it is now found. On the other hand, ammonia (both free and albuminoid) and phosphates have been detected in some samples of well waters. Whether these components have been derived from infiltrated surface water, or whether their presence indicates the pre-existence of abundant animal life from which the oil has formed, is a matter which only extensive research will decide.

APPENDIX.

I. "Das Erdol." Engler.
II. J.S.C.I., 1923, June 29, pp. 287, 288, & Joun. Inst. Petr., 10, 41, p. 87. 1924.
III. J.I.P.T., 8, 31, p. 193, April, 1922. "Significance of the interpretation of the Chemical Analyses of Seepages," by J. E. Hackford.
IV. Imperial Mineral Resources Bureau. Pamphlet on Vanadium.
V. "Oil shales of the Lothians."
VI. "Data of Geochemistry." Clarke.
VII. "Oilfield Development and Petroleum Mining." A. B. Thompson.
VIII. J. Chem. Soc., 1904, Aii., p. 766.
IX. Economic Geology. "Concentration and circulation of the elements from the standpoint of Economic Geology." Lindgren.

Some Characteristics of the Hydrocarbons in Mid-Continent Kerosene.[1]

By C. R. WAGNER.

IT is a well-recognised fact that Mid-Continent (Oklahoma) crude, even in the lower boiling-point fractions, gives a product which is very different from products of the same boiling-points produced from Pennsylvania crude. The automobile tourist who measures the value of gasoline solely by its Baumé gravity[2] can never be convinced that 58·0 gravity gasoline at St. Louis may have as good a distillation range as 62·0 gravity gasoline at Bradford, Pennsylvania. It is also very commonly said that this difference in gravity is due to an admixture of naphthene (cyclohexane) derivatives with paraffin hydrocarbons in the Oklahoma crude.

It was thought worth while to make some tests to ascertain, if possible, the character of the hydrocarbons present in the Oklahoma crude. It had been frequently noted that it was very difficult by ordinary methods to secure a product which would be unattacked by 66° Bé sulphuric acid (93·19 per cent. H_2SO_4). This fact suggested the presence of aromatic compounds. Attempts to freeze out paraffin hydrocarbons from heavy gasoline and kerosene fractions were fruitless, even at temperatures as low as –50° C., causing considerable doubt as to the presence of compounds of this series in any but the lightest fractions of the petroleum. The method of Moore, Morrell, and Egloff[3] for separating the con-

[1] Paper read before, and published by permission of, the Petroleum Division of the American Chemical Society, at the 66th Meeting, Milwaukee, Wis., Sept. 10-14, 1923.

[2] All gravities given, Baumé or specific, were taken at 15·6°/15·6° C.

[3] Chem. Met. Eng., 18, 396 (1918).

stituents of a special naphtha of specific gravity 0·7527 (56·5 Bé) was tried. This naphtha, as well as all other oils investigated, was made by topping methods, which insure the presence only of compounds originally present in the crude oil. It had a boiling-point range[1] of 100° to 160° C.

One thousand cubic centimetres were treated at –10° C. with liquid sulphur dioxide (in the ratio 2 parts oil to 1 part sulphur dioxide) and the sulphur dioxide was evaporated from the lower layer. After neutralising with sodium hydroxide and washing with water about 30 c.c. of a slightly fluorescent oil were obtained, which had a specific gravity of 0·8388 (37·2 Bé) and the same boiling-point range as the original naphtha. This oil gave the formolite[2] reaction for aromatic compounds and was readily attacked by nitric and sulphuric acids.

Before going further with the work, qualitative tests were made on two other fractions, one of specific gravity 0·7927 (47·0 Bé) and with a boiling-point range of 146° to 210° C., and the other of specific gravity 0·8132 (42·5 Bé) and with a boiling-point range of 192° to 240° C. With great surprise it was found that the quantity of SO_2-soluble constituents increased roughly in proportion to the increase in specific gravity and average boiling-point. The specific gravity of these SO_2-soluble fractions also increased with the rise in boiling-point. Because of the larger proportion of the SO_2-soluble compounds in the heavier cuts, and because of the greater ease of securing a closer fractioned oil in considerable quantities, it was decided to carry on the investigation with this heavy fraction.

Several treatments of 1-litre quantities gave percentages of SO_2-soluble oil ranging from 4·6 to 6·0, with an average of 5·4 per cent. The procedure followed was to agitate the oil vigorously with one-third its volume of liquid sulphur dioxide at –10° C. or lower. After allowing to settle, the lower layer was removed and a second treatment made in exactly the same manner as the first. Sometimes a third treatment was made when the second yielded an appreciable quantity of soluble oil. After evaporating off the sulphur dioxide both the soluble oil and the insoluble oil were washed with large quantities of cold water, neutralised with strong caustic, and again washed with water. In every case it was found that the boiling-points of the two fractions were unchanged. The specific gravity of the insoluble oil ranged from 0·8100 (43·2 Bé) to 0·8081 (43·6 Bé), and the specific gravity of the soluble oil from 0·9159 (23·0 Bé) to 0·9094 (24·1 Bé).

[1] Bur. Mines, Tech. Paper 214.

[2] Holde, "Examination of Hydrocarbon Oils," p. 38.

Where the sulphur in the original oil had been 0·046 per cent., the insoluble oil now contained 0·016 per cent., and the soluble oil 0·54 per cent. This soluble oil nitrated very readily with dilute nitric acid at the temperature of the steam bath, forming a red viscous liquid, which resisted all attempts to crystallise it. The product formed by action of concentrated nitric acid alone or in the presence of concentrated sulphuric was essentially the same, but the reaction with concentrated nitric acid proceeded with explosive violence. It could only be controlled by keeping both acid and oil cooled by ice and salt and adding the acid very slowly.

It was thought that the presence of these sulphur compounds might be the cause of this violent reaction, and attempts were made to remove them by fractional distillation, by distilling with mercury, mercuric oxide, copper oxide, metallic sodium, and lead oxide. Finally, fuming sulphuric acid was used, but none of these methods materially reduced the sulphur content.

Several gallons of a specially processed low-sulphur oil were prepared in the hope that the SO_2-soluble fraction would be correspondingly low in sulphur. No attempt was made to determine the quantity of SO_2-soluble oil in the sample, because the treatment which it had received made it certain that some of these fractions had been removed. When it was found that the SO_2-soluble oil was very low in sulphur, enough was treated to give about 2500 c.c. of the SO_2-soluble oil. This had a specific gravity of 0·941 (23·3 Bé) and a boiling-point range of 198° to 244° C.

This 2500 c.c. of oil was subjected to repeated fractional distillation at 5 m.m. pressure. (It had been discovered in the preliminary work that some decomposition and some polymerisation occurred when these fractions were distilled at atmospheric pressure.) In this way four main fractions were accumulated. Table I gives the results of an analysis of these fractions. Molecular weights were determined by the freezing-point method, using recrystallised benzene.

The individual fractions were cooled down by a mixture of alcohol and carbon dioxide snow to ascertain their melting-points. Practically the entire fraction solidified within a range of 2° C. Temperatures were taken by means of a toluene thermometer, and are not corrected: I, −70° C.; II, −65° C.; III, −48° C.; IV, −28° C. They are without doubt more accurate than the purity of the fractions.

Fraction II, when nitrated, gave, as in other experiments, a dark red, viscous liquid which could not be recrystallised. (The reaction with concentrated acid was as violent as in preliminary experiments.) It was soluble in sodium hydroxide or sodium bicarbonate, being reprecipitated by acids. A nitrogen determination gave

TABLE I.—ANALYSIS OF SO_2-SOLUBLE FRACTIONS FROM MID-CONTINENT CRUDE.

Fraction.	Distillation range at 5 m.m.	Specific gravity.	n^{20} D.	C.	H.	S.	Molecular weight.	Molecular Formula suggested.	Calculated analysis. C.	H.	Calculated molecular weight.
I.	71 to 82	0·8697	1·4925	88·71	11·15	0·045	168	$C_{12}H_{18}$	88·88	11·12	162
II.	82 to 93	0·8866	—	89·19	10·99	0·021	173	$C_{14}H_{26}$	89·36	10·64	188
III.	93 to 104	0·9117	1·5238	89·56	10·30	0·054	167	$C_{12}H_{14}$	89·66	10·34	174
IV.	104 to 115	0·9383	1·5448	90·27	9·49	0·062	177	$C_{14}H_{18}$	90·32	9·68	186

TABLE II.—ANALYSIS OF SO_2-INSOLUBLE FRACTIONS FROM MID-CONTINENT CRUDE.

Fraction.	Distillation range at 5 m.m.	Specific gravity.	n^{20} D.	C.	H.	S.	O (by difference).	Molecular weight.	Formula suggested.	Calculated Molecular weight.
I.	71 to 82	0·8100	—	—	—	—	—	—	—	—
II.	82 to 83	0·8109	1·4500	85·73	13·71	0·010	0·55	182	$C_{13}H_{26}$	182
III.	83 to 88	0·8118	—	85·38	14·09	0·011	0·52	179	$C_{13}H_{26}$	182
IV.	88 to 93	0·8123	—	85·27	13·85	0·012	0·87	—	—	—
V.	93 to 95	0·8125	—	84·86	14·35	0·013	0·78	191	$C_{14}H_{28}$	196
VI.	95 to 103	0·8120	1·4517	85·46	14·21	0·010	0·32	—	—	—

9·55 per cent. nitrogen, the calculated value for $C_{14}H_{16}(NO_2)_2$ being 10·05 per cent. Further nitration with fuming nitric acid caused little change in the appearance of the nitrated substance and added no more NO_2 radicals. Exposure to the air caused a gradual decomposition, evolving nitrous acid and leaving a lustrous, resin-like body. Traces of acid catalysed this decomposition. An ether solution, after being washed free of acid, remained perfectly stable for months. An attempt was made to reduce some of this nitrated substance by hydrogen sulphide and by the action of hydrochloric acid on granulated tin. No amines could be recovered from the tarry mass left after either reduction.

It is almost impossible to get data from the literature on compounds similar to those met with in this work. Their odour very closely resembles the naphthalene oil cut from coal tar, and it is believed that they are partly hydrogenated substituted naphthalenes. Their specific gravity, index of refraction, carbon-hydrogen ratio, and boiling-points clearly eliminate the cyclohexane derivatives and the olefins. With the exception of Fraction I, the benzene derivatives are likewise eliminated. A search through Beilstein, Engler-Höfer, Abegg and *Chemical Abstracts* resulted in finding only a few references to compounds similar to those suggested, and the properties given for those are similar to the ones found in this laboratory. No other class of compounds which would include those studied here could be found. If the writer's assumptions were correct, I would be a substituted hexahydronaphthalene, II and III substituted tetrahydronaphthalenes, and IV a substituted dihydronaphthalene.

The SO_2-soluble oil was also subjected to repeated fractional distillation under a pressure of 5 m.m. These cuts were practically unaffected by 66° Bé sulphuric acid, and had a very pleasant odour and a low sulphur content. Table II gives the analysis of these fractions.

The index of refraction, as well as the analysis of these compounds, indicates that they belong to the C_nH_{2n} series, and that paraffin hydrocarbons are largely, if not entirely, absent. A further evidence of the absence of paraffin hydrocarbons is found in the melting-points, which were determined as described above: II, –43° C.; V, –29° C.; VI, –29° C. Their inactivity toward sulphuric acid makes it almost certain that they belong to the cyclohexane series.

The writer wished to acknowledge his indebtedness to S. A. Montgomery and R. S. Lane for invaluable assistance rendered in this work, and to Leroy McMaster for use of laboratory and library facilities at Washington University.

REVIEWS.

OIL AND GAS CODE. Business Code Co., New York. Howard & Jones, Ltd., London.

This code, which contains nearly 40,000 words and phrases, is designed to meet general requirements in sending cables in connection with the petroleum industry. Each word or phrase is represented by a five-letter code word and a figure of five numbers. The phrases are arranged in alphabetical order according to the noun or verb to which they refer, and a number of code words are left blank throughout the book for the insertion of additional phrases. Two very useful features are: (1) a table by means of which words mutilated in transmission can be deciphered correctly, this being so arranged that the first two, the middle, or the last two letters can be easily traced, and (2) several phrase tables which enable any phrase to be coded.

The book is well produced, and should prove of valuable assistance to those who use the cable for the transmission of lengthy messages. A. W. E.

FUEL OILS AND THEIR APPLICATION. By H. V. Mitchell, F.C.S., M.Inst.P.T. Sir Isaac Pitman and Sons, London. 5s.

This little book, written in concise and colloquial language without being overburdened with chemical and engineering formulæ, should prove of practical utility to all interested in the application of fuel oils for commercial purposes.

The author illustrates and explains the uses of a wide range of typical burners and oil-burning installations.

Chapter 4, in particular, should be of use to the works manager and works engineer, as it not only deals with calorific values in a chatty manner, but draws particular attention to the necessity and the means of ascertaining and overcoming waste in factory plants.

The author, presumably, had to notice in passing experiments carried out with colloidal fuel. He, however, makes perhaps a little too much of it, since he devotes almost a chapter to this fuel and draws attention to it in the preface.

The author quotes this Journal as his authority for a paper on the subject by Messrs. Bates and O'Neill; but no such paper has, in fact, been published in this Journal.

In dealing with colloidal fuel the author seems to be a little inconsistent, having regard to his very apt hints on the removal of water and solids from oil on page 117. N. A. A.

OIL WELL DRILLING METHODS. By Victor Zeigler, A.M., Ph.D. John Wiley & Sons, New York. Chapman & Hall, London.

This book deals in a non-technical manner with the various operations connected with the drilling of wells for oil, and contains a large number of well-known illustrations of machinery and tools. While we are not in accordance with all the statements made by the author, the book contains a good deal of information likely to be useful to those for whom it is written, *i.e.*, "to the student, to the man entering the oil business, and to the man interested in oil because of his investments." As usual with books placed on the market by these publishers, the volume is well produced. W. S.

CORRECTION.

Journal No. 41. Page 111. Reviews.

The publisher of "Le Mazout," by E. Davin, should read A. D. Cillard.